ROYAL SOCIETY.

REPORTS TO THE MALARIA COMMITTEE.

THIRD SERIES.

CONTENTS.

LONDON:
PRINTED BY HARRISON AND SONS, ST. MARTIN'S LANE.
1900.

Price Two Shillings.

DECEMBER 31, 1900.

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CONTENTS.

REPORTS, &c., FROM DRS. STEPHENS AND CHRISTOPHERS, WEST COAST OF AFRICA.

"The Agglutination of Sporozoits. (Preliminary Note.)" By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received August 3, 1900.

It has been shown by Grabitschewsky for spirochetes and by Landsteiner for spermatozoa that with these bodies specific agglutinative reactions can be got.

We proceeded to investigate whether, under any conditions, sporozoits were capable of being agglutinated, and we have found that such is the case.

The salivary glands of anopheles were dissected out, and an emulsion was then readily made, either under a cover-glass, or in a hanging drop. In preparations made with normal saline the sporozoits float freely in the liquid. When, however, instead of using normal saline, human serum is used, we get the phenomenon of agglutination. The sporozoits concentrate more or less readily into masses, and after a certain time a few only are found free.

This reaction is shown with various low dilutions of normal serum.

Having shown that sporozoits are capable of agglutination, one might reasonably deduce that a truly specific action might be obtained between sporozoits and certain sera, as has been shown by Grabitschewsky and Landsteiner for spirochetes and spermatozoa, and as hold good very generally between an infective body and the resulting serum.

Our experiments in this direction are at present much hindered by the fact that only 2 per cent. to 3 per cent. of anopheles in Lagos contain sporozoits in the salivary glands. Such a specific serum we should expect to find in those constantly exposed to inoculation with sporozoits. Further, it may be possible that the serum of a malarial patient has such a specific action. We have already obtained an agglutination of sporozoits with such a serum in a dilution of 1 : 15 normal saline; whereas so far the action of normal serum has only been got in dilution of 1 : 5.

Further experiments are required before it can be shown that these reactions are definitely specific. If they be so, their bearing on the

questions of malarial immunity and possibly blackwater fever will be considerable.

We have further observed that sporozoits at ordinary room temperature (26°·5 C.) exhibit in serum active writhing movements, which continue for many hours. Further, in specimens kept in serum at 35° C. for twenty-four hours, many sporozoits become circular in shape, an appearance which appears to be due to the close apposition of the free ends of the sporozoit. Such forms stain readily, and then give the appearance of a ring with a mass of chromatin on the periphery, and a clear central area. The resemblance of these forms to the ring form of the parasite is striking, but whether accidental or not further observation must decide.

Lagos, West Coast of Africa,
July 14, 1900.

"The Malarial Infection of Native Children." By J. W. W. Stephens, M.D. Cantab., and S. R. Christophers, M.B. Vict. Received October 1, 1900.

(Plate 1.)

In a previous report we gave the results of our examination of the blood of a number of natives, having regard mainly to the relation between the age of the children and the percentage of those infected.

In this report we shall consider rather the character of the infection itself, and the variations that occur in it from time to time.

The difficulties experienced by us in obtaining the blood of native children has made this paper incomplete in many respects.

We shall consider the following points:—

1. Asexual forms (schizonts).
2. Sexual forms (gametes).
3. Leucocytic changes and pigment.
4. Periodicity of sexual and asexual cycles.
5. The immunity of adult natives.

It must be understood that in speaking of a case of malaria in children, we are referring only to the presence of parasites; the children are perfectly well, and present none of the characteristic signs observed in Europeans affected with malaria. In some cases, however, the temperature has reached 100° F., and further observations may show that the statement may require some qualification.

The parasite found by us so far, both in Lagos and on the Gold Coast, has been exclusively the æstivo-autumnal (malignant tertian) or tropical parasite of Koch. As altogether 639 cases have been examined by us without the occurrence of a single tertian or quartan parasite, we

believe that the latter forms do not exist among the natives of the West Coast. We think it very possible that certain forms of gametes bearing a superficial resemblance to tertians and quartans, and described by us later, have been so described by some authors. The asexual forms presented are quite characteristic. Thus we get the young forms, the so-called rings, with a stained chromatic body generally at some point on the periphery, and also the larger oval forms such as we have described in an early report; both these forms are unpigmented. We have never yet encountered a segmenting parasite in native blood, and we can only recall two instances in which we have seen segmenting parasites with a central pigment mass in European blood, and in both these cases the parasites were included in polynuclear leucocytes, and occurred in severe attacks of fever.

1. We have had, so far, no opportunity of following a case through a period of twenty-four or forty-eight hours, so are unable to state whether a tertian periodicity in the time of development of the schizonts is exhibited by the parasite in native children, as is the case in Europeans.

The asexual parasites, then, met with in the native blood are morphologically the same as those in Europeans, viz., æstivo-autumnal.

2. *The Sexual Forms* (*Makrogametes*, *Mikrogametocytes*).—It is here that native blood presents many points of divergence from European blood—features that have hitherto not been recorded. While in European blood subsequent to an attack of fever it is the crescentic form of the gamete that is encountered, in native blood while gametes are exceedingly common yet the crescentic form is rare, the gametes assuming the spherical forms found in simple tertians and quartans. At first we were inclined to think that here, owing to the climatic conditions, the change from the crescentic to the round form of the gamete occurred with peculiar rapidity—the change is known to be favoured by warmth and moisture; later it became evident that this would not explain the facts, as films made on dry days with the greatest rapidity showed the same absence of crescents, and, further, intermediate forms, such as would have been seen if the change were occurring on the slide, were not present. We are convinced, on the contrary, that the crescentic form is not an essential distinctive feature of the æstivo-autumnal parasite, but that in native blood the conditions are such that here, as in the case of the simple tertian and quartan parasites, male and female spherical gametes are present in the circulating blood.

Why in European blood, and occasionally also in native blood, crescentic forms are found, we have no facts to explain.*

* It may be well to briefly mention the technique adopted by us, for we think its simplicity recommends itself. In tropical work this is certainly a merit, for we know of excellent observers who are deterred simply by the multiplicity of details

In a stained preparation containing fully developed gametes, we are at once struck by the fact that these are of two kinds :—

(α) The mikrogametocyte (the male gamete) showing pigment collected in the centre, or occupying a narrow band across the central zone. The pigment is brownish yellow, lighter in the centre and spherical in shape. At the periphery of the gamete are a number of sharply stained bodies (chromasomes) roughly triangular in shape, and often showing a small central relatively unstained portion. The chromasomes are more or less regularly distributed peripherally. Frequently they are 12 or even 20 in number. (See Plate 1.)

(β) The makrogamete (the female gamete), showing pigment irregularly distributed over the whole of the gamete, spicular, dark, and quite easily distinguished from the pigment of the male gamete. The gamete is uniformly and only slightly tinged with stain, or at most shows one or two ill-defined deeper stained particles. It is not uncommon to find one or more "vacuolic" areas.

The differences in the distribution and in the character of the pigment in the two forms of gamete are well marked.

Celli in his description of the male and female gamete does not draw attention to this. Whether or no it occurs in European blood we do not know, but in native blood the difference is most characteristic.

The fact that in the mikrogametocyte we have always a central mass of pigment with a peripheral distribution of chromosomes, recalls the arrangement of a segmenting parasite. It seems reasonable to conclude that the chromasomes (mikrogametes) are really formed by a process analogous to that of segmentation and the formation of schizonts.

recommended by various authors. The finger is pricked with a triangular surgical needle and a clean glass slide made to touch the exuding drop of blood. The drop thus received on the slide is then spread by the shaft of the needle in a broad, even streak along the slide. On first touching the drop with the needle-shaft a little time should be given for the drop to run along the needle for some distance by capillarity. The most perfect films are thus obtained. The slides are then placed in a pot of absolute alcohol for five minutes. The merits of hæmatein (*purissimus*) as a stain for malarial parasite we have already pointed out. The beautiful results obtained in staining gametes confirms our original statements. A saturated alcoholic solution is made. To 10 c.c. of this solution are added 50 c.c. of alum solution (alum 50 grammes, water 1000 c.c.). The solution keeps for months, and does not precipitate stain. The stain is best kept in a pot and the slides dipped in. The slides may be left in some hours without over-staining, but excellent results are got in 5—20 minutes. The exquisitely clear chromatin staining often resembles results obtained by Romanowski's method.

On examination of a slide prepared in this way, the oil is applied directly to the slide without using a cover-glass. If it is required to preserve the specimen subsequently, the oil is washed off with a little xylol, and then Canada balsam and cover-glass applied to prevent the growth of mould. If the slides, however, are wrapped in clean paper in a closed box they are perfectly good without any cover-glasses a year later.

As a rule, the mikrogametocytes are in excess of the macrogametes. We have occasionally, however, seen instances in which no mikrogametocytes were found, but we believe that this is quite exceptional.

Frequency of Male and Female Gametes.

Case	I	♂ 5	♀ 3
,,	II	♂ 5	♀ 9
,,	III	♂ 2	♀ 1
,,	IV	♂ 3	♀ 4
,,	V	♂ 4	♀ 1
,,	VI	♂ 13	♀ 3
,,	VII	♂ 4	♀ 1
,,	VIII	♂ 0	♀ 2
,,	IX	♂ 17	♀ 9
	Total	♂ 53	♀ 33

The next peculiarity that we have noticed is the occurrence in very many of these bloods of immature forms of the gametes. According to Celli, these are only met with in European blood in the peripheral circulation in pernicious cases, otherwise they occur exclusively in the bone marrow. We were struck in examining the blood of native children by the occurrence of pigmented parasites of a type which we had not before seen, and by a closer examination it became evident that all stages of the pigmented forms occurred, very often together with the ordinary unpigmented ring forms, and that the former formed a gradation up to the typical gamete we have described. In the younger forms it is not easy to distinguish the differences of pigment that are characteristic of the adult forms, but it can often be seen that some of these stain more deeply than others, and already show a commencing formation of chromasomes. We find these forms about one-third the size of a red cell, and irregular in shape; from this they can be traced up to the adult form occupying the whole of the cell.

Again, we find in these bloods quite young forms not having the appearance of ordinary rings. As regards number, these non-annular forms are comparable only to the gametes, which in high degrees of infection are never so numerous as the ring forms. They stain uniformly around the periphery, and do not possess a chromatic body. They have usually a few fine grains of pigment. In their earliest form these bodies are unpigmented. We believe them to be the earliest stage in the development of gametes. Examples of these forms are seen in the accompanying plate.

We have, then, in native blood parasitic forms, *i.e.*, spherical forms of gametes and developmental forms of the same, which we do not

encounter in European blood. We believe that these forms have been wrongly described by some authors as tertians and quartans.

Not uncommonly the female gamete is associated with a well-marked stippling of the red cell in which it lies. The spots do not stain definitely, but they are large and easily seen. Whether this occurs in the case of male gametes we cannot positively state. The appearance of the red cell is a very characteristic and peculiar one.

3. *Leucocytes and Pigment.*—We have in various reports drawn attention to the marked mononuclear increase in malarial fever, and we have considered that the change is of considerable diagnostic importance. The change is, we think, to be regarded as an indication of reaction to infection, *i.e.*, as a sign of infection, not as a sign of immunity. Though the native child, as we have said, shows none of the characteristic symptoms of malaria, yet it is noticeable to what an extent this mononuclear change is marked in certain cases; in fact, it is uncommon in these young children, who are at some time or another always infected, to get a quite normal leucocytic value. The mononuclear increase is often extreme, in other cases slight. We give some examples in Table IV, though it has been impossible for us to follow out this change hourly as we have done in the case of Europeans. When the age of immunity is reached the high mononuclear value becomes normal, so that, although at this time there is a marked active immunity, there is no increase in the large mononuclear elements (see Table IV).

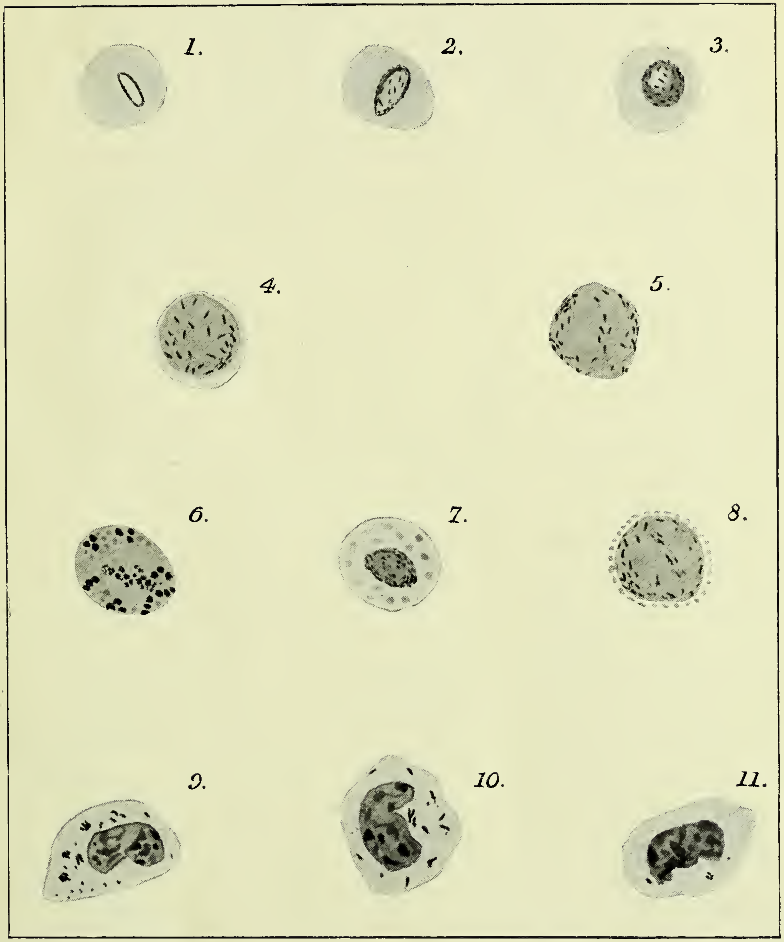
We would draw attention to the character of the pigment in the leucocytes. Sometimes this is of the spicular character noticed in the makrogamete; at other times we get isolated clumps, slightly granular in appearance, as if derived from the segmenting of schizonts. Occasionally we find the large mononuclears containing extremely fine dust-like pigment.

The presence of pigmented leucocytes we consider as evidence on the whole of the formation of schizonts, since numerous gametes may occur with few or no pigmented leucocytes. It is noteworthy, too, how extraordinarily difficult it is to find pigment in some slides, even along with a large parasitic infection. Search over large areas of blood-films is necessary before a negative result can be accepted as true. In native blood, pigment has never been observed by us in polynuclear leucocytes; in European blood, also, it is only in the more severe cases that it is found in these.

The extreme rarity, both in European and native blood, of parasites, included in leucocytes, is evidence that the action of the latter on the parasite cannot be phagocytic in the earlier sense of the word, as used by Metchnikoff. The parasite itself before or after its death is rarely seen included in the leucocytes, though it is quite possible that some secretory product of the leucocyte causes their destruction.

4. *Periodicity of Sexual and Asexual Cycles.*—We might have expected

PLATE 1.



To illustrate paper on Malaria in Native Children.

Description :—

1. Young form of Gamete.

2, 3, 4. Older forms of the same.

5. Makrogamete.

6. Mikrogametocyte.

7, 8. Makrogametes showing punctation of red cell in which they are situated.

9, 10, 11. Types of pigmented leucocytes met with in native children.

that owing to the fact that the children in any particular house are constantly exposed to infection from anopheles, the blood examinations would show an infection of asexual parasites and gametes at different stages of development, and so mixed that no definite order or sequence could be evolved. But this is not so. An examination of the tables will give a more vivid idea of the nature, extent, and persistence of infection than a mere description could.

Table I shows at a glance the frequency with which gametes occur. Further, it appears that, contrary to expectation, there is a sequence in the occurrence of parasites. Thus, in Case I, asexual parasites and pigmented leucocytes only were found for a period of a month; then gametes appeared, and continued for about a fortnight, when further observations were discontinued.

Case II shows that asexual parasites and gametes practically co-existed for a period of over six weeks.

Case III. Gametes only were found during nine days' observations. Ten days later asexual parasites first appeared and continued without gametes for nearly a month, when gametes again reappeared without the disappearance of the asexual parasites.

Case V. Gametes persisted for a month with an occasional appearance of asexual parasites.

So that it would appear as if there was a succession of gametes, in the same way as we have a succession of developments of asexual parasites leading to the ordinary febrile attacks of Europeans. In Case III there is apparently about a month between the appearance of two gamete cycles; but this may be accidental, as observations were not prolonged over a sufficient number of months and in a sufficient number of cases to establish this interval with any certainty.

Table II shows the same thing in children from a less highly infected area; whilst Table III shows it where immunity due to age is producing weaker infections.

The appearance of gametes (crescents) following on the asexual (schizont) cycle in European fevers must be regarded as the expression of the regular periodicity of the cycles, some indications of which we believe are afforded by this examination of native blood.

The time of persistence of the schizont and gamete cycles cannot well be observed in Europeans, as the periodicity is interfered with by quinine, but we have in these children an indication of the cycle which leads to the fortnightly or monthly fevers which have been described in Europeans.*

We cannot, in the present state of our knowledge, attribute any part to the gametes in the production of relapses.

It has been hitherto generally accepted that the gamete (crescent)

* "On peut dire d'une façon générale que les rechutes ont lieu souvent à la fin des septénaires." Laveran, 'Traité du Paludisme," p. 165.

was peculiarly resistant to quinine; but as we no longer can attribute to them this function of producing relapses, it must follow that the parasite in some form can exist in a cinchonised body, probably in the internal organs. It has too often been assumed that the absence of parasites in the peripheral blood signifies an absence of malarial infection, but in native children, as we have seen, a negative blood examination on a particular day is frequently followed by a positive on the subsequent one, and it is not an uncommon experience that Europeans habitually using quinine may suffer from slight fever attacks (in all probability malarial) in which parasites are very scanty or absent.

If we consider generally the condition of infection of natives, we see that we have two conditions :—

(1) A condition of infection of young children without febrile disturbance. This may be due to a natural insusceptibility of the native African to malaria, or it may be due to an immunity transmitted from the parent to the offspring. This question could be best determined by observing whether a child from a non-endemic area would, on introduction to an endemic area, suffer from typical symptoms as a result of infection.

(2) We have further a condition of active immunity in the adult native, an immunity acquired as the result of many years (10) of infection with parasites. The immunity is accompanied (see Table III) by a progressively scantier development of parasites, and is quite comparable to that described by Pawlowsky* for infection with micro-organisms.

Whether the serum of such an immune person would have any curative properties, and what reactions *in vitro*, agglutinative or parasiticidal, it might possess, further observations are necessary to determine.

Native malaria is a field of study hitherto completely neglected. Prolonged observation of native children, with post-mortem examinations, cannot fail to throw much light on the life-history of the parasite in the human organism.

* A. O. Pawlowsky, "Zur Frage der Infection und der Immunität," 'Zeitschrift für Hygiene und Infections-Krankheiten. Drei und dreissigster Band. Zweites Heft,' 1900.

TABLE I.—Showing Course of Infection in Native Children (highly endemic area).

	Case I, 4 y.	Case II, 4 y.	Case III, $\frac{4}{12}$ y.	Case IV, 3 y.	Case V, $\frac{6}{12}$ y.	Case VI, 5 y.	Case VII, 2 y.	Case VIII, 5 y.	Case IX, 4 y.
26 : VI : 00	P^1 — $L^{f.n.}$	— — $L^{f.}$	— $G^{n.}$ $L^{n.}$	—	— $G^{n.}$ —	—	Neg.— —	—	— — L^1
29 : VI : 00	— — L^1	—	— $G^{n.}$ $L^{f.}$	—	— $G^{n.}$ —	—	—	—	—
30 : VI : 00	$P^{n.}$ — —	P^1 G L	— $G^{n.}$ $L^{f.}$	—	—	— G^1 —	Neg.— —	—	—
5 : VII : 00	—	Neg.— —	— G^2 L^4	—	— $G^{v.n.}$ —	— — L^1	Neg.— —	—	Neg.— —
8 : VII : 00	$P^{n.}$ — —	— — L^1	— — $L^{f.}$	—	$P^{f.}$ $G^{f.}$ —	$P^{n.}$ — —	—	—	—
15 : VII : 00	$P^{v.n.}$— —	P^5 G^3 $L^{f.}$	$P^{f.}$ — —	$P^{f.}$ — L^2	— G^1 L^1	P^2 — —	$P^{f.n.}$— —	$P^{n.}$ G^1 L^1	$P^{n.}$ — —
22 : VII : 00	$P^{v.f.}$— L^1	$P^{n.}$ $G^{n.}$ L^4	$P^{f.n.}$ — —	$P^{v.n.}$— L^1	$P^{f.}$ $G^{v.n.}$ L^3	$P^{f.}$ — —	$P^{v.f.}$— L^1	— $G^{f.}$ —	$P^{f.}$ — —
26 : VII : 00	$P^{f.}$ — L^2	P^1 G^1 L^3	— — L^2	— — L^2	—	Neg.— —	$P^{f.}$ — —	—	$P^{v.n.}$— —
29 : VII : 00	— $G^{f.}$ —	—	P^2 — L^3	P^2 — —	— $G^{v.n.}$ —	Neg.— —	Neg.— —	— $G^{v.n.}$—	P^4 — —
1 : VIII : 00	Neg.— —	— $G^{f.}$ L^4	P^3 — —	$P^{v.n.}$ G^1 $L^{f.}$	— G^4 —	Neg.— —	$P^{n.}$ G^1 —	P^2 — —	Neg.— —
3 : VIII : 00	—	$P^{f.n.}$ G^2 L^2	— — L^3	$P^{v.n.}$— —	P^5 — L^1	P^4 — —	— G^3 L^2	Neg.— —	Neg.— —
5 : VIII : 00	$P^{f.n.}$ G^8 —	$P^{n.}$ G^1 L^8	P^2 — —	$P^{n.}$ G^2 —	Neg.— —	$P^{n.}$ — —	$P^{f.n.}$ G^6 —	Neg.— —	P^2 — —
7 : VIII : 00	$P^{f.}$ G^9 —	$P^{n.}$ — L^1	$P^{v.n.}$— —	P^4 — L^1	$P^{v.n.}$— —	P^5 — —	P^4 G^1 —	— G^1 —	$P^{f.}$ — —
10 : VIII : 00	P^2 $G^{n.}$ L^4	$P^{f.n.}$ G^6 L^{15}	— G^2 —	P^2 G^1 L^1	—	Neg.— —	P^5 — L^1	— G^1 —	— G^1 —
12 : VIII : 00	P^2 G^1 —	$P^{v.n.}$— —	$P^{f.n.}$ G^5 L^{10}	P^1 G^1 —	P^4 G^3 L^4	P^1 G^2 —	P^{10} G^1 L^1	P^1 G^2 —	$P^{f.}$ — —
14 : VIII : 00	P^1 — —	— G^1 L^3	$P^{f.n.}$ G^2 L^{12}	$P^{n.}$ — —	—	Neg.— —	Neg.— —	Neg.— —	Neg.— —
16 : VIII : 00	Neg.— —	— G^2 L^2	P^3 — —	—	— G^{10} —	—	—	—	Neg.— —

P = asexual parasite. G = gamete. L = pigmented leucocyte. n = numerous; f.n. = fairly numerous; v.n. = very numerous; f = few; the numbers 1, 2, 3, &c., denote how many parasites, &c., found.

Table II.—Showing Course of Infection in Native Children; the infection is less than in Table I, the children coming from a less endemic area.

	Case I, 2 y.	Case II, 8 y.	Case III, 9 y.	Case IV, 3 y.	Case V, 5 y.	Case VI, 2 y.	Case VII, 5 y.	Case VIII, 4 y.	Case IX, 8 y.
4 : VIII : 00	$P^{f.n.}$ — L^1	— G^n L^1	$P^{v.n}$ — L^1	P^6 — —	$P^{f.n.}$ — L^2	$P^{n.}$ — —	P^5 — L^1	$P^{f.}$ — —	—
5 : VIII : 00	P^5 G^3 —	$P^{v.n.}$ — —	P^7 — —	— — L^2	P^n — —	P^3 G^2 —	P^5 — —	—	Neg. — —
6 : VIII : 00	P^2 G^1 L^8	$P^{v.n.}$ — —	P^1 — L^1	Neg. — —	P^5 — —	—	—	$P^{f.n.}$ — —	P^2 — —
7 : VIII : 00	P^3 — —	Neg. — —	Neg. — —	Neg. — —	—	$P^{n.}$ $G^{n.}$ L^2	— G^1 —	$P^{f.}$ G^1 —	—
8 : VIII : 00	P^5 — —	P^3 — —	Neg. — —	Neg. — —	P^2 — —	$P^{f.}$ G^8 —	P^3 — —	P^{12} — L^1	Neg. — —
9 : VIII : 00	P^1 — L^2	Neg. — —	Neg. — —	Neg. — —	Neg. — —	$P^{f.}$ $G^{n.}$ —	P^2 — L^1	—	— — L^1
10 : VIII : 00	Neg. — —	—	—	—	—	—	—	—	—
11 : VIII : 00	—	Neg. — —	Neg. — —	Neg. — —	Neg. — —	P^1 G^{16} L^2	P^3 — —	—	Neg. — —
12 : VIII : 00	Neg. — —	Neg. — —	—	Neg. — —	—	— G^2 —	— G^7 —	—	Neg. — —
13 : VIII : 00	Neg. — —	— G^1 —	—	Neg. — —	P^4 — —	— G^2 L^4	— G^3 L^5	$P^{n.}$ — L^3	Neg. — —
14 : VIII : 00	Neg. — —	Neg. — —	Neg. — —	P^5 — —	— — L^2	— — L^2	— — L^4	—	Neg. — —
15 : VIII : 00	—	Neg. — —	—	P^2 — —	P^2 — L^1	— G^3 L^1	— G^1 —	$P^{f.}$ — L^2	Neg. — —
17 : VIII : 00	P^3 — —	Neg. — —	Neg. — —	Neg. — —	P^1 — —	P^1 G^1 —	— G^1 —	Neg. — —	P^2 — —

Table III.—Showing Diminution of Infection with increase in Age.

	31 : VII : 00.			2 : VIII : 00.			8 : VIII : 00.			14 : VIII : 00.		
Case I, 6 y.......	P^4	—	—	—	G^3	—	P^3	—	—		—	
„ II, 8 y.......	—	—	L^3		—			—			—	
„ III, 4 y.......	P^3	—	—	—	G^8	—	Neg.	—	—		—	
„ IV, 5 y.......	—	G^9	—	—	G^3	—		—			—	
„ V, 6 y.......	—	G^5	—	Neg.	—	—	—	G^1	—	—	—	L^3
„ VI, 7 y.......	P^5	—	—	Neg.	—	—		—		Neg.	—	—
„ VII, 6 y.......	—	G^1	—	Neg.	—	—		—			—	
„ VIII, 6 y.......	Neg.	—	—	Neg.	—	—	—	G^2	—		—	
„ IX, 6 y.......	Neg.	—	—	Neg.	—	—	—	G^1	L^1		—	
„ X, 7½ y,.....	P^1	G^1	—	P^4	—	—	—	G^1	L^1	—	—	L^1
„ XI, 6½ y.....	—	G^3	—	—	G^2	—	Neg.	—	—	P^4	—	—
„ XII, 7 y.......	P^1	G^1	L^1	Neg.	—	—	Neg.	—	—	Neg.	—	—
„ XIII, 5 y.......	P^1	G^3	—	—	G^1	—	—	—	L^2	Neg.	—	—
„ XIV, 6 y.......	$P^{f.n.}$	—	—	—	G^2	—	P^6	G^2	—	P^6	—	—
„ XV, 6½ y......	Neg.	—	—	Neg.	—	—	Neg.	—	—		—	
„ XVI, 5 y.......	—	—	L^6		—		P^2	—	—		—	
„ XVII, 4½ y......	—	G^1	L^4		—		P^1	—	L^3		—	
„ XVIII, 5 y.......	—	—	L^1	Neg.	—	—	P^7	G^7	—		—	
„ XIX, 7½ y......	—	$G^{f.n.}$	—	P^3	—	—	$P^{f.n.}$	G^5	L^2	—	G^1	—
„ XX, 6½ y......	—	—	L^3	P^6	G^2	—	—	—	L^4	—	—	L^3
„ XXI, 4½ y......	Neg.	—	—		—			—			—	
„ XXII, 8½ y......	Neg.	—	—		—		Neg.	—	—		—	
„ XXIII, 5½ y......	—	$G^{f.n.}$	—	$P^{f.n.}$	—	—	P^1	—	—	—	—	L^1

Table IV.—Showing Leucocytic Changes in Native Children.

Age.	Nature of infection.	Large mononuclear.	Polynuclear.	Small mononuclear.	Eosinophyl.	Remarks.
$\frac{8}{12}$	G^{scanty}	24	24	45	7	Young children; showing parasites.
$\frac{10}{12}$	— — L	26	24	49	1	
2	$P^{\text{n.}}$ — $L^{\text{n.}}$	30·6	23·6	41	4·6	
3	$P^{\text{n.}}$ — —	21·3	48·6	26	4	
3	$P^{\text{n.}}$ — $L^{\text{n.}}$	52	26	19	3	
5	— $G^{\text{sc.}}$ $L^{\text{n.}}$	34·5	33	24	8·5	
3	— $G^{\text{sc.}}$ $L^{\text{sc.}}$	30	42	27	1	
5	$P^{\text{n.}}$ — $L^{\text{sc.}}$	19	47	22	12	
1	neg.	13·2	63	22·2	1·2	Young children; showing no parasites in blood.
2	neg.	12	32	44	12	
3	neg.	24	39	34·5	1·5	
4	neg.	24·5	49	24·5	2	
9	$P^{\text{sc.}}$ — L	25	36	29	7·5	Limit of age at which infection takes place.
10	G^{scanty}	24	40	26	9	
11	neg.	16·5	40	16·5	16·5	
12	neg.	12	37	34	17	
20	neg.	8·2	69	18·5	5·2	Adults.
22	neg.	13	65·4	13·1	8·5	

"On the Destruction of Anopheles in Lagos." By J. W. W STEPHENS, M.D. Cantab, and S. R. CHRISTOPHERS, M.B. Vict.

Received October 1, 1900.

[PLATE 2.]

In most towns and villages in the rainy season small pools are numerous, and water oozes from the ground in many places. At this time the breeding places of anopheles abound. They are more

numerous in towns than would appear from a carefully made "spot map," for they are easily overlooked in native enclosures and other sites difficult of access; and, again, new pools are formed, and others previously free may on a second visit contain larvæ.

In the dry season the conditions are very different. Late in the dry season, prolonged search may be necessary before any breeding places can be found, and indeed large areas may not contain a single breeding place. Mere observation of breeding places has led to totally erroneous ideas as to the real distribution of anopheles at this time. The few existing pools give an inadequate idea of the number of anopheles in a district. There may be many thousands of winged anopheles widely distributed not originating from the scanty stock of breeding places then present, but remaining over ("hibernating") months after the pools they were bred in have disappeared. At the end of the dry season, the real distribution of anopheles would be indicated by a spot map showing the native huts of a district. In nearly every hut anopheles can be found by one practised in detecting them: feeding at night on the inmates, and secreted by day in the dirty thatch, they pass through much or the whole of the dry season without breeding. We have in a previous report given many examples of this condition. It will suffice here to recall those of Freetown and Accra, where, although the number of pools was very small, anopheles were present throughout the greater portion of the town, and always ready to lay their eggs in the artificial (test) pools constructed by us.

In spite, then, of the at first sight promising conditions during the dry season, it is doubtful whether at this time it is possible to influence the number of anopheles in the ensuing rains. To destroy breeding places in the dry season would in many places be an easy task, but unless destructive measures are capable of keeping a decided check on breeding places when they are most numerous, *i.e.*, in the rains, efforts to diminish anopheles will probably not have any appreciable effect.

Physical Features of Lagos.

Lagos is situated upon low-lying alluvium, and is surrounded by extensive lagoons. The western half of the small island of Lagos is completely occupied by the town, the native huts in some places extending to the water's edge. Several small lagoons penetrate into the island, and are shown on the accompanying map. (Plate 2.) Around each of these sheets of water we find very numerous and squalid huts.

The whole island of Lagos is low lying, the highest point not being above 20 feet above sea level. A considerable tract, however, in the centre of the town lies above 10 feet above sea level. This central comparatively elevated area is approximately level, but its margins sink rapidly towards the lagoons. Between this sloping ground and

the lagoons there is a strip of land of varying width which lies almost at lagoon level. The extent of this strip of low land is shown by the 5-foot contour line on the accompanying map of Lagos.

The ground upon which the town is built consists of porous sand. Even the heaviest rain is rapidly absorbed in the central elevated tract; so that in a few days after continuous rain, all surface pools have disappeared. The subsiding water, however, emerges again around the borders of this tract, forming a line of oozing water extending around nearly the whole island after the main rains. The upper limit of this line did not rise above the 5-foot contour line.

Anopheles Breeding Places.

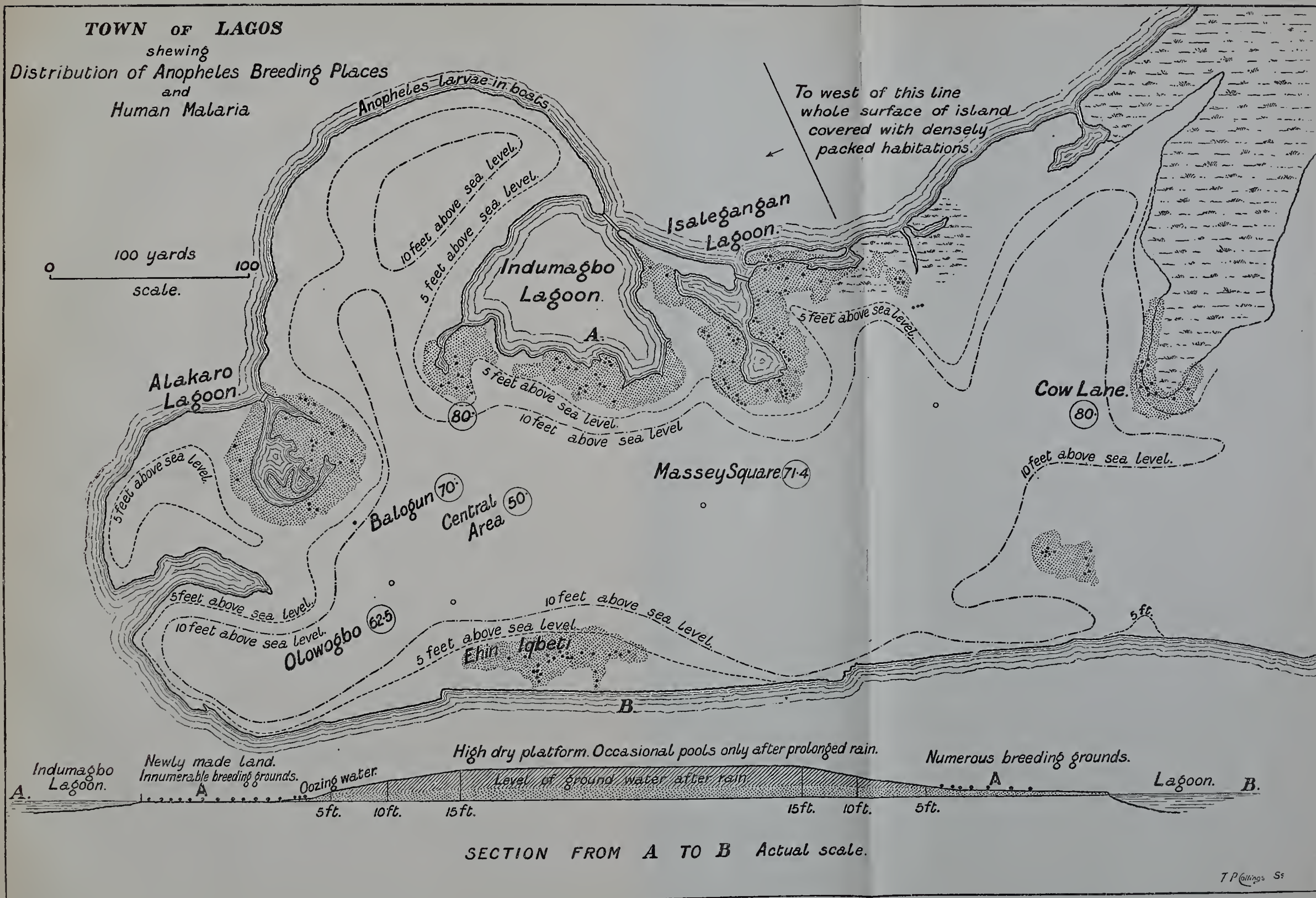
The distribution of the water described above determines very largely the distribution of anopheles breeding places. On the higher ground, owing to the transient nature of the pools, breeding places are very rare and last but a short time. Below the upper limit of the oozing water, however, breeding places are present everywhere in large numbers. The marginal strip of low ground especially is the site of extremely numerous breeding grounds, and it is where this strip is broadest that anopheles are present in greatest profusion.

Mention has been made of several minor lagoons which extend into the island of Lagos. Around the margin of these the low-level strip reaches its greatest extent. Much of the ground is land reclaimed by the deposition of mud, shell banks and refuse. This land is barely above the level of the lagoon water, and is completely waterlogged. It is everywhere covered with innumerable pools and puddles, very many of which contain anopheles larvæ. The number of pools is so great that there is no limit to the number of anopheles that might be produced, and the actual resulting number is probably determined by the food supply of the adults or other causes.

The pools here also are not always of a permanent nature, and the breeding places vary from week to week. The accompanying map shows those breeding places seen in a single week in July. They do not, however, represent the total number, as owing to the extent of water and the boggy nature of the ground the pools were often difficult of access.

In the less densely populated portions of the strip small maize gardens are common. In the furrows of these, anopheles are always abundant. In this portion of the town it is also a common thing to find anopheles larvæ in shallow earthenware vessels which are not in use but which contain rain-water.

On reaching the higher ground above the narrow strip described, a very marked difference in the number of breeding places is at once evident.


TOWN OF LAGOS
shewing
Distribution of Anopheles Breeding Places
and
Human Malaria
Anopheles larvae in boats
To west of this line whole surface of island covered with densely packed habitations.
0 100 yards 100
scale.
10 feet above sea level.
5 feet above sea level.
Indumagbo Lagoon.
A.
Isalegangan Lagoon.
5 feet above sea level.
Alakaro Lagoon.
5 feet above sea level.
80·
10 feet above sea level
Cow Lane.
80·
Massey Square 71·4
10 feet above sea level.
5 feet above sea level.
Balogun 70·
Central Area 50·
5 feet above sea level.
10 feet above sea level.
Olowogbo 62·5
10 feet above sea level.
5 feet above sea level.
Ehin Igbeti
5 ft.
B.
Indumagbo Lagoon.
Newly made land.
Innumerable breeding grounds.
Oozing water.
High dry platform. Occasional pools only after prolonged rain.
Level of ground water after rain
Numerous breeding grounds.
Lagoon.
A.
B.
5ft. 10ft. 15ft. 15ft. 10ft. 5ft.
SECTION FROM A TO B Actual scale.
T P Collings Sc

The Lagoons.—As the small lagoons themselves were shallow it was thought possible that anopheles bred in these also. They were never detected, however, by us, though careful search was made.

An examination of the salinity of these lagoons showed that the salt was inconsiderable, and indeed fell short of that in wells in Accra in which larvæ abounded.

It is probable that it is on account of the open nature of these large sheets of water that anopheles do not breed in them. In small pools upon the mud, separated by only a few inches from the open water, larvæ are, however, sometimes present.

The Destruction of Breeding Places.

The following is an ennumeration of the chief sources of anopheles in Lagos:—

1. The strip of land surrounding the following lagoons:—
   Isalegangan lagoon,
   Indumagbo ,,
   Alakaro ,,
   also a tract of swamp and small lagoons along the N.E. shore of Lagos.
2. The district of Ehin Igbeti.
3. The swamp margins and low-lying districts to the east of Lagos.
4. Occasional temporary pools in the streets after heavy rains.

No. 1 includes the main portion of the breeding grounds of Lagos. These areas consist almost entirely of ground such as has already been described, namely, waterlogged land abounding in pools and breeding places and densely crowded with native huts.

To deal effectively with such extensive areas is a work of great magnitude. Culicides could not be employed effectively. Drainage must be almost impossible. The only method which appears at all feasible is filling with sand. We have seen that, even in the heaviest rains, water does not ooze from the ground except at a level below 5 feet above sea level. Were then the whole low-level strip raised by the deposition of some porous substance (sand) to the height of 5 feet, the required result would be obtained. The surface water from the areas above this level then, especially if facilities for its doing so were increased by pipes or other means, would reach the open lagoon without appearing at the surface. There would be no necessity to advance far into the shallow lagoons, as we have seen that it is only on their shores that breeding places occur.

At the present time a swamp is being filled by sand in this way; and were this process persevered in no doubt in time the western

portion of Lagos Island, upon which the town is built, could be freed from areas at present giving rise to myriads of anopheles.

Even if no attempt be made to do away with such low lands in towns, the reclaiming of lagoons and the making of new waterlogged land by the deposition of rubbish, shells, and mud cannot be too strongly condemned. In Lagos there are at present considerable tracts of land that have been formed in this way, and these are always conspicuous as the breeding places of anopheles.

No. 2. Ehin Igbeti is chiefly of interest in that it is the district which supplies the anopheles which frequent the majority of the European houses in Lagos. It is a tract of swampy ground, not very extensive, lying behind the houses on the Marina. The extent of this area can be judged from the accompanying map. This area, as it is the nearest to European quarters, should be the first of the sources to be abolished, whilst the extensive areas just discussed are for the most part a considerable distance from these. Ehin Igbeti is not so low as the swampy ground around the lagoons, though it is less than 5 feet above sea level. The filling up and increased drainage of this source of anopheles ought to be both a very practicable and advantageous proceeding.

No. 3, a very extensive swamp, is situated to the east of Lagos. Around its borders are very numerous breeding places. This region would present great difficulties to any method of treatment. There is also towards the eastern end of Lagos an area of low ground with breeding places lying close behind the hospital, prison, and European quarters which could, by combined filling up and drainage, be removed fairly readily.

No. 4. The temporary pools formed during the heavy rains on the more elevated grounds are by no means numerous. Of the numerous cement gutters in the town the majority are free from breeding places, being scoured out by the least rain. In certain places gutters with irregular bottoms have been formed; these, as well as gutters needing repair, very frequently have breeding places. Apart from the gutters, however, pools are liable to form on the sandy surface of the roads, but these, as will be seen from the map, are not nearly so numerous as those in the special districts described above.

The Result of Destructive Operations.

Were this thorough treatment carried out, could we be sure that anopheles would disappear and malaria be absent?

We have seen that the central high portions of Lagos are very free from breeding places, and except in the height of the rains it is a most difficult matter to find any at all. In this locality we should expect, then, a diminution in the endemic malaria present, as shown by a

lessened percentage of infected children. The result of the examination of children from various districts in Lagos is shown in the following table and the map. (Plate 2.)

Table I.—Showing Endemic Malaria of Lagos.

District.	Age.	Percentage infected.
Olowogbo	Below 2 years ..	62·5
	2—5 years	66·6
	5—10 years	—
Massey Square	Below 2 years ..	71·4
	2—5 years	50·0
	5—10 years	—
Market Square	Below 2 years ..	100·0
	2—5 years	71·4
	5—10 years	—
Balogun Square............	Below 2 years ..	—
	2—5 years	70·0
	5—10 years	—
Cow Lane District..........	Below 2 years ..	80·0
	2—5 years	75·0
	5—10 years	25·0
Strictly limited central area as shown on map.	Below 2 years ..	50·
	2—5 years	40·0
	5—10 years	—

It is evident that there is a slight diminution in the percentage of infected children, but by no means a marked one. How far, then, the most complete operations will affect the malaria of a large town we hesitate to say. There may be a certain number of anopheles in the higher portions of Lagos derived from the numerous wells scattered throughout the town. We were, however, unable to detect larvæ in those examined by us, which for the most part contained deeper and purer water than the wells of Accra. Possibly some spread of anopheles takes place from the periphery of Lagos to the centre. So closely associated indeed are malaria and the native in Africa, and so wonderfully constant is the presence of anopheles where natives are collected in numbers, that we doubt whether any operations, now possible, directed against anopheles will do much to diminish the

danger of malarial infection. In fact, in Africa the primary aim should not be the destruction of anopheles, but rather to remove susceptible Europeans from the midst of malaria. To stamp out native malaria is at present chimerical, and every effort should rather be turned to the protection of Europeans.

"Note on Malarial Fever Contracted on Railways (under Construction)." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October 1, 1900.

[PLATE 3.]

The railway camps, plans of which accompany this note, afford a particularly good example of the conditions under which malaria is contracted.* The requisite conditions are :—

1. Native children supplying the infection.
2. Infected anopheles in the native huts.
3. Collections of huts inhabited by adult natives also favour the transmission of malaria, as although the source of infection may be more distant, yet anopheles infected elsewhere abound in such huts.

In railway camps we have all these conditions in the immediate vicinity of the European dwellings, and they completely explain the prevalence of fever in these camps.

The conditions shown in the plans were present in every camp without exception on the Lagos Government Railway.

Plan I is that of Aro, at present the terminus of the Lagos Government Railway. It shows (1) native servants' quarters, (2) labourers' camp, (3) native villages. All these contained numerous anopheles, and the number containing sporozoits was at least 25 per cent. Although the native servants' quarters did not contain many children, yet migration of infected anopheles undoubtedly took place, as shown by the arrows on the plan. They thus supplied condition 3.

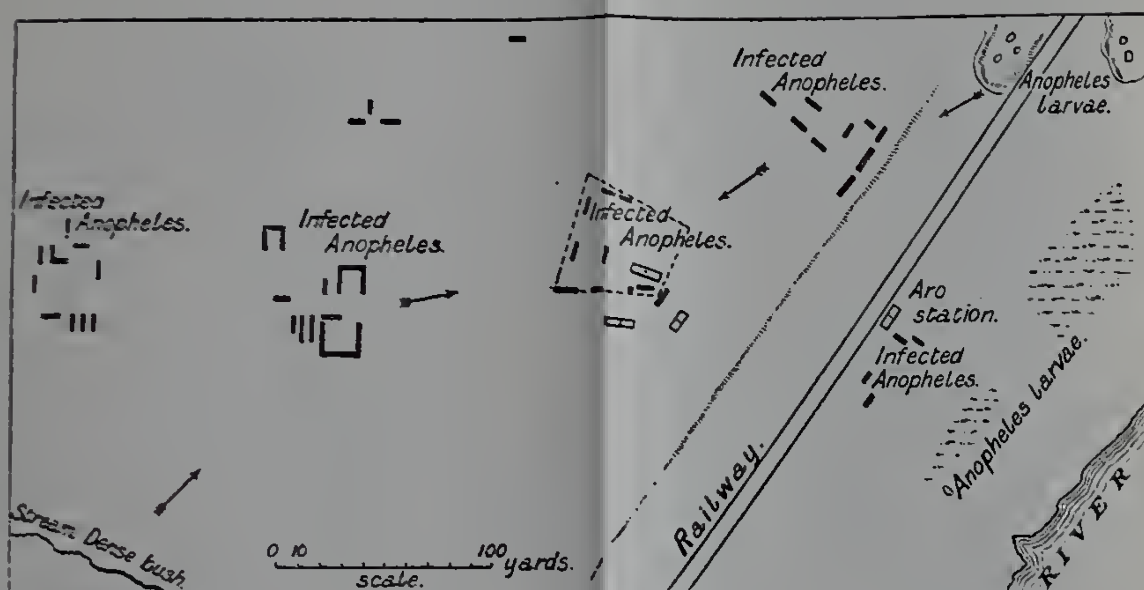
Plan II. Loko Meji Camp: Numerous native servants and a few women and children live in the huts immediately adjoining those of the Europeans. About 50 per cent. of anopheles caught in these huts were infected. A considerable native village within a distance of 200 yards contained numerous children and infected anopheles.

Plan III. Railhead Camp: occupied by a single European. The same conditions—children, native servants, infected anopheles, native villages close at hand.

* *Vide* "The Native as the Prime Agent in Malarial Infection of Europeans," also "Segregation of Europeans," in our Reports to the Malarial Committee of the Royal Society.

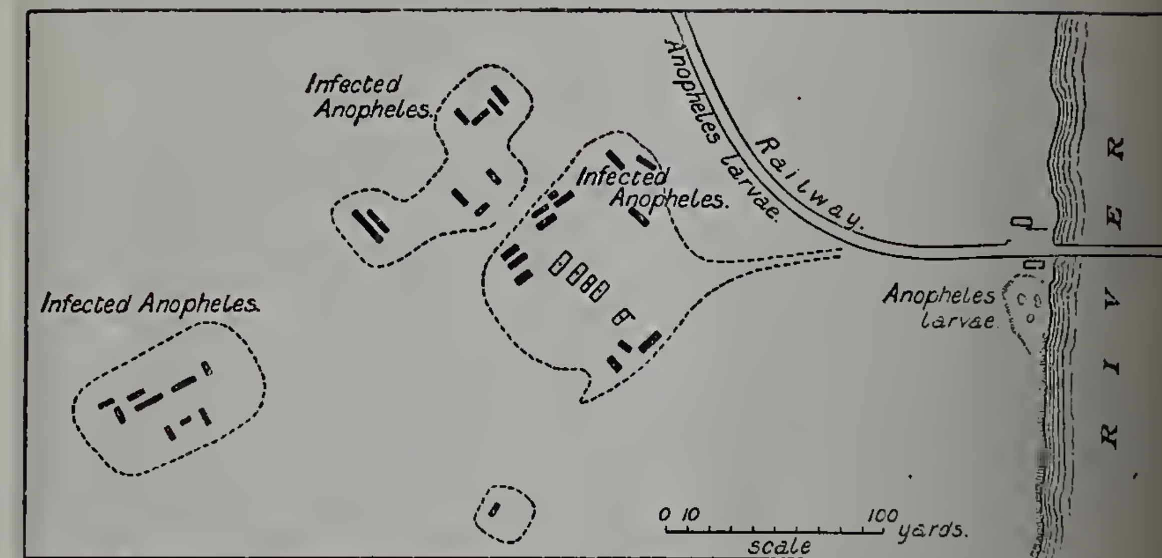
PLATE 3.

PLAN I.



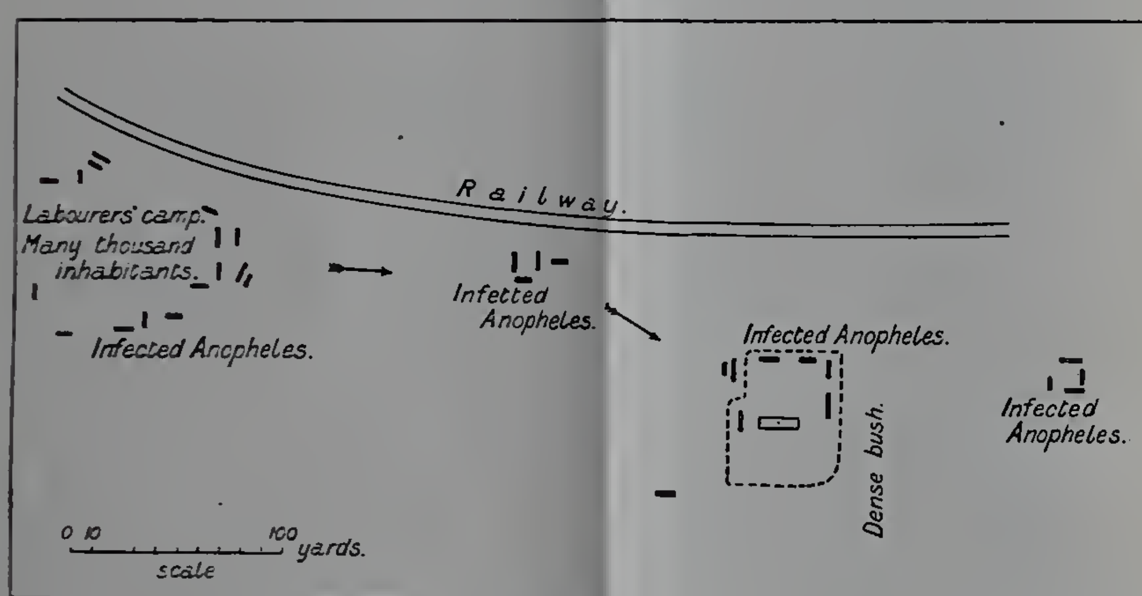
Terminus of line open for traffic.
European quarters ▭.
Native huts and compounds ı ⊓.
The arrows indicate spread of Anopheles.

PLAN II.



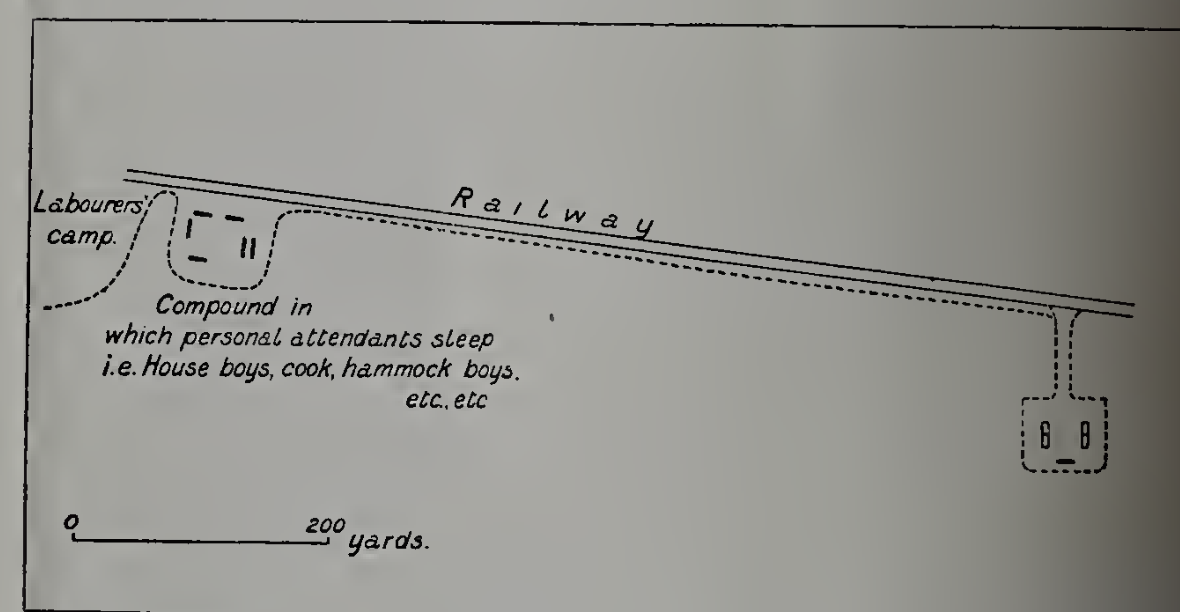
Large Railway camp
European quarters ▭
Native quarters ▬

PLAN III.



The camp of a single European at rail-head.
European's quarters ▭.
Native huts ▬
The arrows indicate probable spread of Anopheles.

PLAN IV.



Ideal camp
Europeans. ▭
Natives ▬

To illustrate Note on Malarial Fever on Railways under Construction.

Prevention of Malaria.

In our report entitled "Segregation of Europeans" (see below), we discuss fully how protection from malaria is to be obtained, and there conclude that the only practical fundamental means is a complete segregation of Europeans from all natives.

This, however difficult in the case of towns, can be easily effected without expense on any railway under construction.

Plan IV illustrates how this can be done.

1. A site should be selected for European dwellings as far as possible from a native village; a mile would undoubtedly suffice.

2. The camp of the native labourers should also be placed at the greatest possible distance (half a mile to a mile).

3. The house servants and others should not sleep in the European compound, but a quarter to half a mile away.

4. One personal servant only should be allowed to remain in the camp at night.

There is nothing impossible in these conditions, and were the medical officer to have the selection of sites and the power to see that segregation was as far as possible carried out, malaria would be far from being so rampant on railways as it now is.

"The Segregation of Europeans." By J. W. W. STEPHENS, M.D. Cantab., and S. R. CHRISTOPHERS, M.B. Vict. Received October 1, 1900.

Koch* has shown that while the native adults of Dutch New Guinea do not suffer from malaria, yet that malarial infection in certain districts among children is a general condition, the percentage of infected cases sometimes being as high as 100 per cent. He also showed that as the age of the children increased the percentage of infected children diminished, so that above the age of ten the immunity of the children was already very great. In this condition of infection of young children we have, further, an accurate index of the endemicity of malaria.

Working independently on the Gold Coast we, too, found† that the infection of native children was a widespread and general condition—that there the age-factor was that which determined the existence or not of infection.

* Koch, "Dritter Bericht über die Thätigkeit der Malaria-Expedition," 'Deutsche. Med. Woch.,' Nos. 17 und 18, 1900.

† Stephens and Christophers, "The Native as the Prime Agent in the Malarial Infection of Europeans." ('Further Reports to Malaria Committee 1900).'

It must be clearly recognised, however, that although we are dealing here with a blood infection, yet the condition is not that which we find in Europeans suffering from malaria. Although parasites are present in both cases, here the similarity ends, for, speaking generally, the children in whose blood there may be very numerous parasites do not appear ill. They run about or attend school, and present none of the well-known symptoms of a malarial attack. Further, this condition, viz., the presence of parasites, is not a transient one, but persists for weeks, months, and, in fact, years. We do not imply that the number of parasites is always the same; on the contrary, it is most variable; but if parasites are not present one day they will be found the next, or the interval in which parasites do not occur may be longer; but, speaking broadly, the condition is one of a constant infection until the age-limit at which immunity appears is reached.

We would appear to have, then, in this condition of infection of native children unaccompanied by manifest signs a state of things parallel to that of trypanosoma in wild game and in rats, and of halteridium in birds.

The parasite found by us so far in native children in Lagos and on the Gold Coast has been the malignant tertian (æstivo-autumnal), and, indeed, out of several hundred cases not a single quartan or simple tertian occurred. The frequency with which gametes occur is very striking, so that the constant presence of infected anopheles in native quarters, as already shown by us, is readily explained.

In the case of Europeans, on the contrary, parasites are rarely found except in definite attacks of fever. Even when present they are extremely few in number, and bear no comparison to the large infections with the ring-form parasites, or with gametes, of native children. An examination of a number of Europeans living in Lagos and in various stations up country showed how at any one time but a very small percentage showed the least trace of malarial infection. Even in the case of Europeans who habitually slept without mosquito nets, and exposed to the risk of constant infection, the same paucity of infection was exhibited. Of twenty-one such Europeans only two showed parasites, and these were in both cases of extreme rarity. Of a considerable number of Government officials and other Europeans who habitually used nets and adopted ordinary precautions, none contained parasites.

These facts are of importance, as they show that the generally-received idea that Europeans derive malaria from pre-existing cases in Europeans requires considerable modification. This factor, it seems to us, sinks into complete insignificance beside that of infection derived from native sources. The normal condition of native children is one of almost continuous infection, and there are therefore many thousands of cases of malaria in large towns. This enormous source of infection has so far escaped recognition. Whilst Europeans live in the midst of

native quarters exposed to infection on all sides, the isolation of such Europeans as may have fever, as has been and is still advocated by some writers, is manifestly futile.

It cannot be too clearly realised by Europeans in these large towns and by those responsible for their health that they are dwelling in the midst of thousands of cases of malaria, none the less dangerous to them though in the native child presenting none of the characteristic signs of an attack of "fever." Malaria is essentially a contagious disease, the contagion being conveyed by the mosquito; the laity must appreciate this fact and refuse to dwell in the midst of contagion. They must recognise that malarial fever is a contagious disease contracted (through the medium of the mosquito) from the native child. Malarial fever, we are convinced, can be avoided most readily by avoiding this source of contagion and living as far removed as possible from native huts. Just as a horse cannot live in a "fly" district, as he becomes inoculated with the fatal tsetse-fly disease by the contagion conveyed from the wild game, so the European living among native children is inoculated by means of the mosquito with malarial fever. The only means of escape is by segregation to avoid the source of contagion.

Hitherto attention has been confined almost entirely to ridding whole towns of anopheles. We are of opinion, from observations recorded in another report, that this is by no means the easy task supposed by many, and that it is likely to be brought about only after many years of gradual improvement in the surface drainage of towns Now, the adult native possesses, as we have seen, an active immunity against malaria, and although living under the same conditions as the children, constantly subjected to the bites of infected anopheles, yet examination of his blood shows that parasites are always absent. It is true that the immunity is not absolute, for occasionally we meet with severe fatal attacks in adults, but, speaking generally, there can be no doubt of the real immunity enjoyed by the adult native.

There is no doubt, then, that to the adult natives of African towns the presence or absence of anopheles is by no means so important a matter as it is to Europeans. The question that is of the most urgent necessity, then, is not so much how large towns with sometimes 40,000 native inhabitants can be freed from anopheles, but how the comparatively small number (at most 200) of Europeans can be protected.

This, we believe, is only to be attained by segregation of the Europeans. In constructing new European houses, the main point to consider is how can they be placed as far as possible from native dwellings. Where a distance of one-quarter to half a mile can be placed between European residences and any native hut, malaria must of necessity become rare.

In Freetown we believe that the segregation of Europeans is only possible by the removal of the whole of the European residences from Free-

town itself; and the proposal to build residences on the adjacent hills is an excellent one, provided the greatest care be taken that no native quarters are in the neighbourhood. If things, however, are allowed to take their course, the new condition may well be worse than the old. For at once quarters for native servants and their families spring up around each European residence, and so the mistake universal on the coast and responsible for nine-tenths of the malaria is perpetuated, namely, living amidst native huts in which malaria and infected anopheles may at all times be found.

At Accra the partial segregation of official quarters has been effected, and we believe with the best results.

In Lagos, finally, if the official and other residences are removed to some up-country station on the railway, as has on several occasions been suggested, again it cannot be too urgently insisted on that on no pretext whatever should residences be built near any native quarter, or that native quarters be allowed to spring up in the midst of the new European quarter. Otherwise the inevitable result will be that malarial fever, contracted from the native children, will be as rife, if not more so, as it is in Lagos at present.

The rigorous isolation of Europeans from natives is, then, the most practical and fundamental means of diminishing the danger of malarial infection. In Africa a complete isolation of Europeans would, we believe, render malaria a comparatively rare disease.

REPORTS, &c., FROM Dr. C. W. DANIELS, EAST AFRICA.

Covering Letter.

Fern Lea, Mossley Hill,
Near Liverpool,
October 21, 1900.

Sir,

I have the honour to forward herewith a final series of reports on the distribution of Anopheles and the Prophylaxis of Malaria.

2. I hope in a short time to forward also some notes on "Blackwater Fever" in that Protectorate.

3. Prophylaxis has been considered exclusively with regard to Europeans. Little could be done in this respect for the natives at present.

4. Specimens of the mosquitoes have been forwarded to the British Museum.

I have the honour to be, Sir,
Your obedient servant,
C. W. Daniels.

The Secretary,
The Malaria Investigation Committee,
The Royal Society.

Distribution of Anopheles in the Lower Shire, Zambesi, and Chinde Rivers.

These observations were made from Chickwawa, at intervals down the rivers mentioned, to the coast, a distance given as 300 miles.

Observations had been previously made at Chickwawa, in October, 1899, late in the dry season; and in February, 1900, late in the wet season.

In other places no observations of much value had been made, as when I went up the river, I did not know the usual breeding grounds.

The observations at Chickwawa differ little from those made

previously. Abundant anopheles larvæ were found in the grass growing in shallows at the edge of the river and in grass-grown sandbanks well out in the stream. They were not found elsewhere. The river was about 2 feet lower than in February; but areas grass-grown and partially submerged were still very extensive.

In the houses culices were much rarer than on previous occasions, but anopheles were very numerous.

It is probable that there was an increase in their numbers as compared with previous occasions.

A native with filaria was persuaded to sleep under a looped-up mosquito net on two nights. In the mornings the mosquitoes found were 100 and 94 anopheles and 6 and 2 culices. In similar experiments made in October and February, 30 to 40 anopheles were found and 60 to 80 culices.

Whether this greater prevalence, absolute as well as relative, indicates that the lower temperature 60–85, at this season of the year, is more favourable to this mosquito than the higher temperatures 85–105 at my previous visits; or that the diminished strength of the stream is the cause of the increase I could not determine, but incline to the former hypothesis.

The Shire river is dependent, for its constant flow, on Lake Nyassa. The permanent streams running into it are few and small, and during the dry season probably insufficient to do more than replace evaporation and absorption.

During the wet season these streams are larger and there are numerous additional streams. The slope from the watershed is steep so that floods are common. These are more important further down the river than Chickwawa.

The next observations were made at Chiromo, about 70 miles down the stream. This station is at the junction of the Ruo, the largest tributary, with the Shire. The banks of both rivers are steep and in the main clean-cut, but in some places at the base of the banks are patches of grass growing into these streams. In the patches anopheles larvæ of at least three species were abundant.

About a quarter of a mile higher up the Shire is a diverticulum of that river ending blindly in a marsh. In this diverticulum, called a lagoon, anopheles larvæ were readily found.

When in flood the Shire pours into this lagoon and floods an extensive area. This area would undoubtedly form an extensive breeding ground during the wet season, as it would form a marsh, well supplied with fresh water at that season. It is immediately behind the township. The "lagoon" itself is of less importance as it is on the leeward side of the settlement and over a quarter of a mile from the greater part of it.

The character of the banks of the Shire varies. In no part of the

lower river are they rocky, but alternate between clean-cut earth banks and more sloping banks with extensive grass-grown areas or grass-grown shoals.

Observations made on the mosquitoes on board the boat 40 miles from Chiromo showed abundance of the small black* anopheles, and amongst some mosquitoes collected for me by Surgeon Gilmour, R.N., of Her Majesty's gunboat "Herald," both these and another anopheles with white barred legs (also found at the north end of Lake Nyassa, Chickwawa, and Chiromo)† were found. These mosquitoes were collected at the junction of the Shire and Zambesi rivers.

Some 50 miles below this point in the Zambesi is the old point of departure for Quilimane, Vicente. Here I spent two days.

In the early days the Zambesi had here a mouth opening at Quilimane, and in flood time the communication has been reopened.

The banks here are steep and clean-cut, as now the main channel of the Zambesi is encroaching on them. We tied up against this bank for the night; no anopheles were found.

About 3 miles inland is a large sugar plantation, Mopea. Through this plantation runs the Kwa Kwa, a narrow stream, the representative of the old Quilimane mouth. This stream is extensively grass-grown and in places nearly covered with aquatic plants (lilies); anopheles larvæ were plentiful.

From this stream is a large back-water, in part artificial, running close to the sugar mills, and used as a source of the water required for the mill. In this back-water and an adjoining pool anopheles larvæ were very abundant.

On the plantation are two large ponds, one of them $1\frac{1}{2}$ miles in length. The water in these is quite fresh and there is much grass growing at the edges into the shallow parts as well as floating masses of aquatic plants; in these situations anopheles larvæ were found.

The water used in the houses is rain water, collected in iron tanks; in none of these did I find anopheles larvæ.

Irrigation is being resorted to for the cane fields and will be more extensively so. The irrigation is of two kinds. In the first, by means of steam pumps water is pumped into trenches from the Kwa Kwa or lakes. The trenches are blocked at certain points and the water is pumped in till the areas fed by these trenches are supplied. By this method the water does not stand very long on the land and the supply is intermittent. No anopheles larvæ found here.

In the second method the waste water from the mill is poured into one of the main trenches and an extensive area is thus partially irrigated. Towards the limit of the area supplied anopheles larvæ are abundant.

* *Anopheles funestus.*

† *Anopheles costalis.*

Here the water supply is continuous but not sufficient for the area to be irrigated, and is another instance of the danger of an irrigation system too extensive for its water supply.

A few years ago this plantation was considered to be very unhealthy but is now not so thought of, as there is very little invaliding, and deaths amongst Europeans are rare.

The following particulars, kindly supplied to me by Dr. Cruikshank, the medical officer of the plantation, show the first occurrence of fever amongst the new-comers during the sixteen months he has been there :—

	Fever under 1 month.	Under 3 months.	In 4th month.	In 7th month.	No fever.
4 have been 16 months	2	1	1	0	
2 " " 15 "	1	0	0	1	
6 " " 2½ "	3	1	0	0	2
3 " " 1½ "	2	0	0	0	1
15	8	2	1	1	3

Thus: Of 15, 8 had fever under 1 month, 2 under 3 months, and of the remaining 5—2 had fever in the 4th and 7th month, and 3 have not yet been resident 3 months.

During this sixteen months there have been four cases of blackwater fever out of a European population reaching forty in the busy season, but much less during the rest of the year.

The morbidity, therefore, is well above the average for British Central Africa. The general appearance of good health, the absence of mortality during the period, and the small number invalided (2), are to be attributed to the regular life on a sugar estate and the attention devoted to the provision of good and varied food, rather than to the natural healthiness of the locality. Quinine, 5 grains, is taken regularly daily by almost all, and some take 10 grains.

The natural breeding grounds of the anopheles on this plantation are so extensive that they could not be dealt with economically, and the prophylaxis would have to be limited to better protection against the mosquitoes.

Anopheles, small black, were also found at night in numbers, about 20 miles further down the Zambesi, at the junction of Chinde and Zambesi rivers, 32 miles from the mouth, and again about 10 miles from the sea up the Chinde river.

As we pass towards the mouth of the river there are two additional actors to be considered :—

(1.) *The Tide.*—At the time of year, July, the river is tidal for about 50 miles, and considerable portions of the bank are left bare when the tide is out.

With low sloping grass-grown banks small pools will be left in which the larvæ could be secure till the next tide. The rise and fall of the tide insures the removal of decomposing vegetation and the purity of the water for a considerable distance amongst the grass on the shallows.

The influence of the tide does not seem to be disadvantageous, as the mosquitoes were abundant 10 miles from the sea.

(2.) *Admixture with Salt (Sea) Water.*—The water, even in the dry season, was quite fresh about 8 miles from the sea. Below this, grass is found in the river in smaller and smaller quantities and is replaced by mangrove swamps completely for the last 2 or 3 miles.

At Chinde I failed to find any anopheles larvæ in the mangrove swamps, in the salt pools above the creeks, or in salt and brackish puddles above high-water mark.

The soil is sandy, and though there were frequent light showers there were no puddles in the sand.

Fresh water is obtained from wells—either European or native. In none of those examined were anopheles larvæ found, and the level of the water was 4 to 8 feet below the surface of the soil. In similar wells elsewhere I have failed to find these larvæ.

There are also a large number of iron tanks filled by rain water from roofs, and water is also collected from the same source in wooden barrels. In many of these there were numerous culex larvæ, but in none did I find anopheles.

On the coast there are frequent showers even during the dry season, though the rainfall is not heavy. The air also is moist. Water will remain for considerable periods in open vessels, the small loss from evaporation being replaced by the rainfall. In one wooden tub I found larvæ of two species of anopheles, but not of the small black anopheles.

I examined many rooms and beds for adult mosquitoes, and found a few anopheles, of a species fairly common, on the lower river, one very large anopheles which I failed to secure and therefore cannot identify, and one, and one only, of the "small black" anopheles. This solitary specimen does not, I consider, conclusively establish the presence of this species of anopheles at Chinde under natural conditions, as the house in which it was found was close to the part of the river bank where steamers are often moored, and, as has been shown, this mosquito is abundant a few miles up the river.

Though at this time of year I found no situations which I thought were suitable for the growth of this mosquito, it is probable that in the more rainy months suitable places do exist. The grass in some of the hollows is of the character I associate with fairly permanent fresh water.

The native gardens are often in such hollows, and I am informed that in the trenches between the rows water often remains for considerable periods.

When the Zambesi is of much greater volume, as it is during the rains, the water is fresh quite close to Chinde, and therefore there will be breeding grounds of the small anopheles much closer to the township, and perhaps larvæ washed down may find a resting place in the creeks.

I have had no opportunity of making observations on the effect of the rainy season at Chinde. Chinde now has the reputation of being a healthy place for residents, though formerly there was much sickness and death amongst residents from the Highlands, &c., on coming down there. Probably this only indicated the maturation of infections acquired in the Upper or Lower Shire rivers.

It will be seen from the above that the "small black" anopheles, in which I have shown crescents develop, is met with in the Highlands on each side of Lake Nyassa and in the whole length of the water system from the north end of Lake Nyassa down the Upper, Middle, and Lower Shire rivers and in their tributaries, down the Zambesi river and its Chinde mouth near to the sea; this is a distance of some 850 miles. I have identified the same mosquito amongst specimens sent me by Dr. Mackae from the south end of Tanganika, so that it has a minimum range extending from a point 18°·50 S. by 36°·50 E. to 9° S. and 31° E.

The mosquito has been identified by persons living on the Tanganika plateau, on the Zambesi and Congo watersheds, and as far up the Zambesi as the Lupata gorge; above that point the river runs through rocky channels, and there are said to be few mosquitoes.

This actual area, though large, is not likely to be the limit of the range of this mosquito, as similar physical conditions prevail over a much larger area, and would include the higher reaches of the Congo and Nile as well as of the Zambesi and the smaller rivers running to the east coast, and also the other fresh-water lakes. The other anopheles are rarely in any number, none of them have as extensive a range or are found under as varied conditions. Whether they can carry any form of malarial parasite has not been determined, but their importance is small compared to that of the other.

Their breeding grounds are similar, often the same.

Distribution of Anopheles Breeding Grounds in the British East African Protectorate. (Uganda Railway.) August, 1900.

The places examined were the island of Mombasa and various points on the Uganda Railway for a distance of 326 miles, and up to an elevation of 5600 feet. The general line was from about 4° S. and 39°·40 E. to 1° S. and 36°·50 E.

The island of Mombasa is of coral formation, and about $3\frac{1}{2}$ miles long by $1\frac{3}{4}$ miles broad. There is no running water, and fresh water is obtained from deep wells and from rain water stored in tanks. In neither of these situations were anopheles larvæ found. Towards the centre of the island there is a depression, and in this water collects.

The shallow pool thus formed contains water in most years constantly, but has been known to dry up in exceptionally dry years.

The pool has shallow edges, and for a great extent is covered with short grass, rushes, and water lilies, but in the centre is quite clear. In no part is the water putrid, peaty, or markedly stagnant.

In this pool anopheles larvæ were found in fair numbers, apparently of three species, including the "small black" anopheles. This was the only place on the island in which I found anopheles larvæ, and I neither found, nor could I hear of, any other natural open fresh water.

The water at selected places on the line was examined. At the more important places which Dr. Sieveking, the principal medical officer of the Uganda Railway, had indicated, I made a stay of some hours; at the less important only short periods. For about 20 miles from the coast rains fall irregularly during the greater part of the year, and at the time of my visit this stretch of the country was green, and pools were present in suitable places. Such places are common, as in making the railway embankments numerous shallow pits are made. These are called "borrow pits," and for convenience in the estimation of work done are made square and of uniform depth, and partitions are left between the pits made by different gangs or contractors. The result is the formation of an infinite series of potential pools all along the railway.

In the first 30 miles of the railway many of these "borrow pits" contained water, and in some of them anopheles larvæ were present in numbers.

Beyond this the pits were dry, but obviously in a wet season might be fruitful subsidiary sources of these mosquitoes.

For the rest of the line the places examined may be considered in the main as permanent breeding grounds, as the water comes from

the higher mountain ranges, including snow-covered mountains, Kilimanjaro, 19,300 feet, and Kenia, 18,620 feet.

In the following list the number of miles is the distance from the coast terminus of the railway, and the second number is the height in feet above sea-level.

Mazeras. 14 miles, 500 feet. Anopheles larvæ in stream and "borrow pits."

Majichumvi. 27 miles, 650 feet. Slowly running stream. *No anopheles larvæ found.* Subsequent inquiries showed that this stream contained much salt. One analysis gave 204 grains of solids in solution per gallon, and 152 of this was sodium chloride. In some "borrow pits" near, larvæ were found (anopheles).

Somburu. 41 miles, 1000 feet. Large pools in granite rock; in some of these anopheles larvæ were found. These pools dry up in prolonged rainless periods, but such are not common so near the coast.

Voi. 100 miles, 1800 feet. River with grass-grown edges. Very numerous anopheles larvæ. On each side of the river is a marsh; in the stagnant pools in it no anopheles larvæ, but only culex larvæ, were found. In a rainy season this marsh is said to be flooded by the river, and then would probably be suitable for the growth of anopheles larvæ, so that these marshes may be a subsidiary or potential breeding ground. "Borrow pits" near railway; dry.

Mtoto. 160 miles, 2500 feet. Stream running in channels over granite rocks in places spreads out and is partially grass-grown. Numerous anopheles larvæ, all of the "small black," were found. No other mosquito larvæ were found.

Masongloni. 182 miles, 2800 feet. Stream much overgrown with grass and abundant algæ. Slowly running. Some anopheles larvæ were found, but those of culices much more abundant.

Kibwezi. 193 miles, 3000 feet. An underground river, running through lava, appears on the surface on the south side of the line as a series of pools, and on the north as a clear running stream. Anopheles larvæ were exceptionally abundant in both situations at any place where there was any obstruction.

Makindo. 207 miles, 3250 feet. A river forms a loop round the settlement about 1½ miles from it. In the grass-grown edges of this stream there were numerous anopheles larvæ. "Borrow pits" are here abundant, but as there had been no rain were all dry.

Kiu. 265 miles, 5200 feet. The stream was in great part dry, but there were some water holes in which the water appeared to be fresh. Anopheles larvæ were found in them.

Nairobi. 326 miles, 5600 feet. The river is much grass-grown and anopheles larvæ were abundant. In pools, in a surrounding marshy area, anopheles larvæ were found, but only in a small proportion of them. The country here is better watered, and though the river was low slight rains are common and the air is moist.

At some distance from the river is a marshy area, through which a small stream runs. In this stream wherever there was any obstruction anopheles larvæ (two kinds) were found.

In a drainage trench from this marsh, in a badly-graded portion, water had collected, and in it anopheles larvæ were found.

The larvæ at this place, the greatest height I reached (5600 feet), were fairly abundant, though perhaps not as much so as they would have been in similar situations in the Shiré Highlands at 3200 feet. They should, I think, be found, though perhaps only in small numbers, for at least another 1000 feet.

On the whole, British East Africa appears to be healthier than British Central Africa. The country (British East Africa) is not so well watered and the undulations are further apart, whilst the permanent settlements are in most cases not so near permanent water.

The temporary or subsidiary breeding grounds are more numerous, as owing to the absence of the tall rank grasses of British Central Africa, water which there would form putrid marshes here forms open pools.

There is a close general correspondence between the reputed unhealthiness of the places examined and the extent and proximity of anopheles breeding grounds, actual or potential.

The anopheles found include in all cases the "small black"; two of the other species occur in British Central Africa, and other larvæ were found which failed to hatch.

Geographical Distribution of Anopheles in Africa.

Several species of anopheles are found in British Central and British East Africa.

The most important is the one I have usually called the "small black" anopheles, which appears to be *Anopheles funestus.*

This species has been shown to carry malaria (crescents). It is the most numerous, the most widely distributed, and the most persistent frequenter of houses.

In one district, and that the most malarious, it is the only anopheles found, and is more numerous than any of the culices there present. These culices have been proved not to carry malaria.

I have found this anopheles at points in the whole course of my journeys, extending over some 1500 miles. Near the equator, rather more than 1° S., it was found in fair numbers in the cool season 5600 feet above sea level. Further south, 15°, it was found, but in very small numbers, at an elevation of 5000 feet, but is common there at 3000 feet. I have found it in numbers at sea level, from 1° to 18° S. These are the limits of my observations.

This indicates a very wide distribution much more extensive than that actually observed. It thrives under climatic conditions where European vegetables are grown, as well as where the vegetation and products are purely tropical.

The accompanying Map and Sections A and B (pp. 36–37) give representations of the raised central portion of Africa, which forms the watershed between the main rivers on the east coast, including the Zambesi, the Nile on the north, and the Congo on the west. The portion underlined with dots indicates the main route I have traversed and found this anopheles; whilst the crosses indicate points which I have not visited, but at which I have proof of the existence of this mosquito.

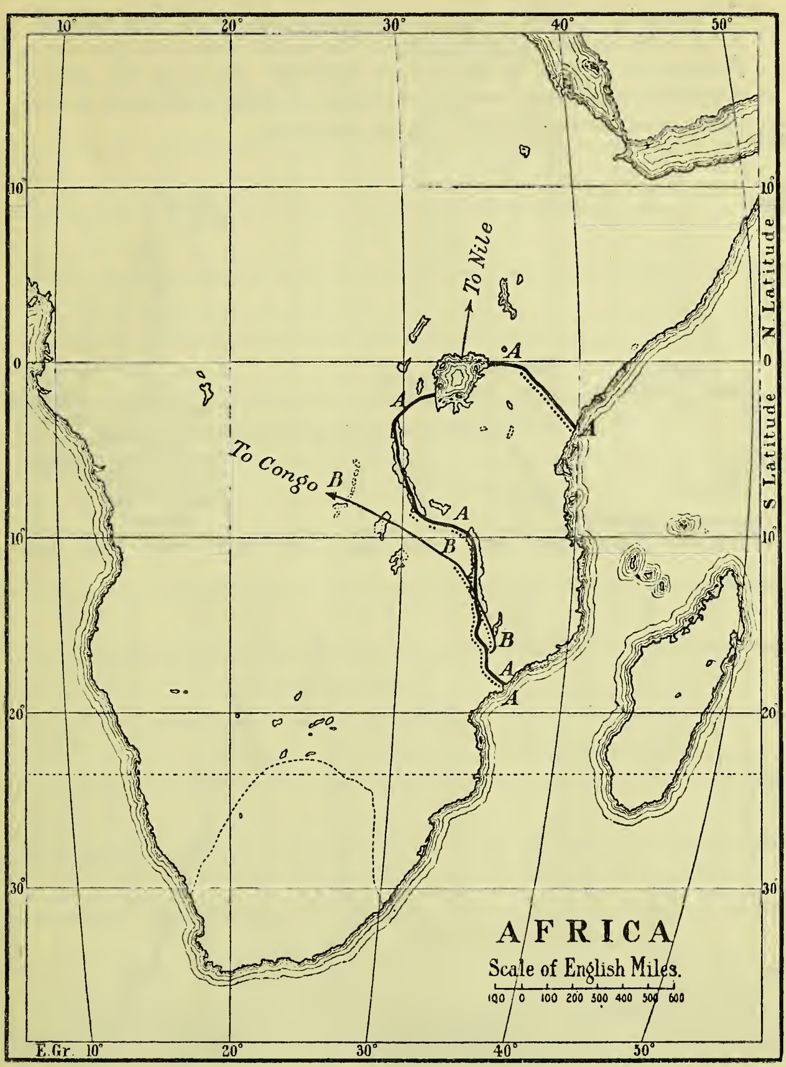
As the climatic and meteorological conditions in the intervening but unvisited portion (marked with solid line only) are similar, it can be fairly assumed, at corresponding and lower heights in this portion also, the same anopheles occurs.

The probable limits of the distribution of this anopheles can, at present, only be inferred. The rainless portion of North Africa would be unsuitable to their life. The connecting waterway, the Nile, with its barren banks and cataracts, would afford little shelter for larvæ, so that it is improbable that the mosquito exists for any great distance beyond the well-watered portion.

To the South frosts occur. I have no experience of that condition in this connection. If prolonged frosts form the southern limit of the distribution of this anopheles, this limit would be indicated by an irregular broken line convex to the north on account of the elevated character of the interior.

The actual coast line is comparatively free from this anopheles, as the river water there is brackish for a great part of the year. The more uniform distribution of the rains and the higher level of the subsoil water favour the formation of pools, and therefore the subsidiary breeding grounds are more permanent and of greater importance than in the highlands in the interior.

The other anopheles are of more limited distribution, but some of them are found at places far apart. Of these the *Anopheles costalis* is of the most importance, as it seems to be the chief agent on the West Coast of Africa. This anopheles is found on the Zambesi and Lower Shire rivers, and in the northern part of Lake Nyassa, but I have failed to find it in the Shire Highlands and Upper Shire rivers. On



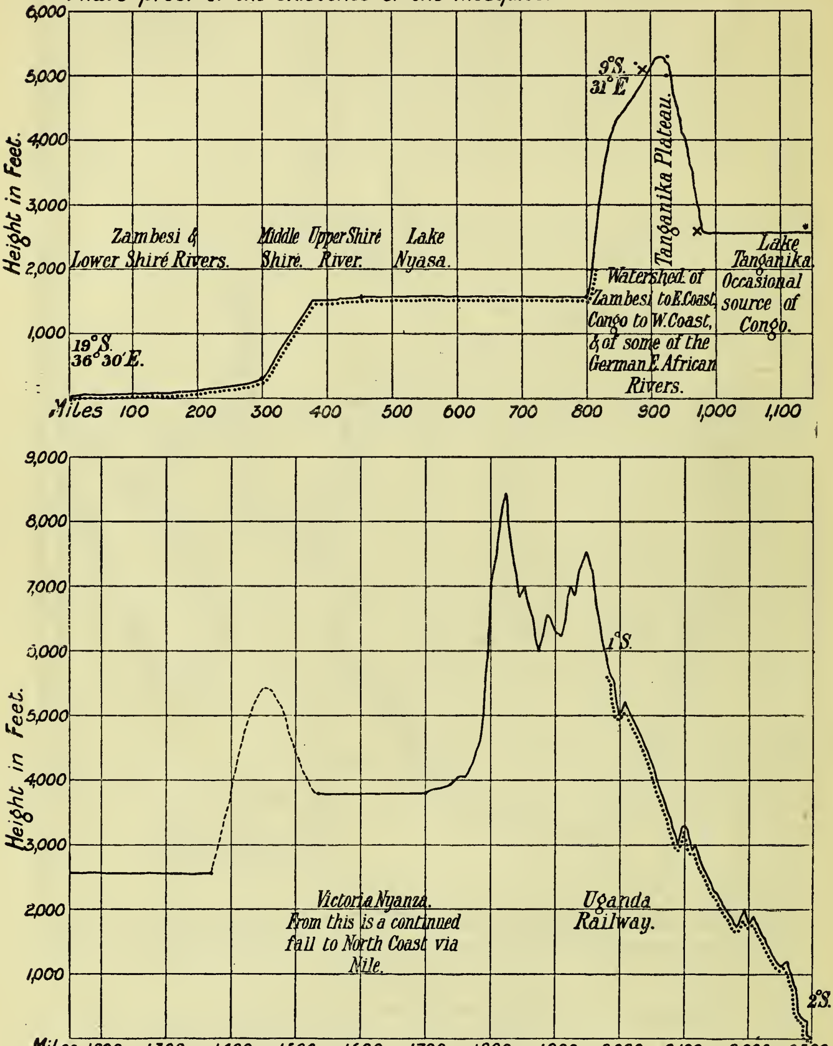
A ——— A } Two routes through which the sections
B ——— B } A & B are taken.

Portions of the routes in which the Mosquitoes have been determined.

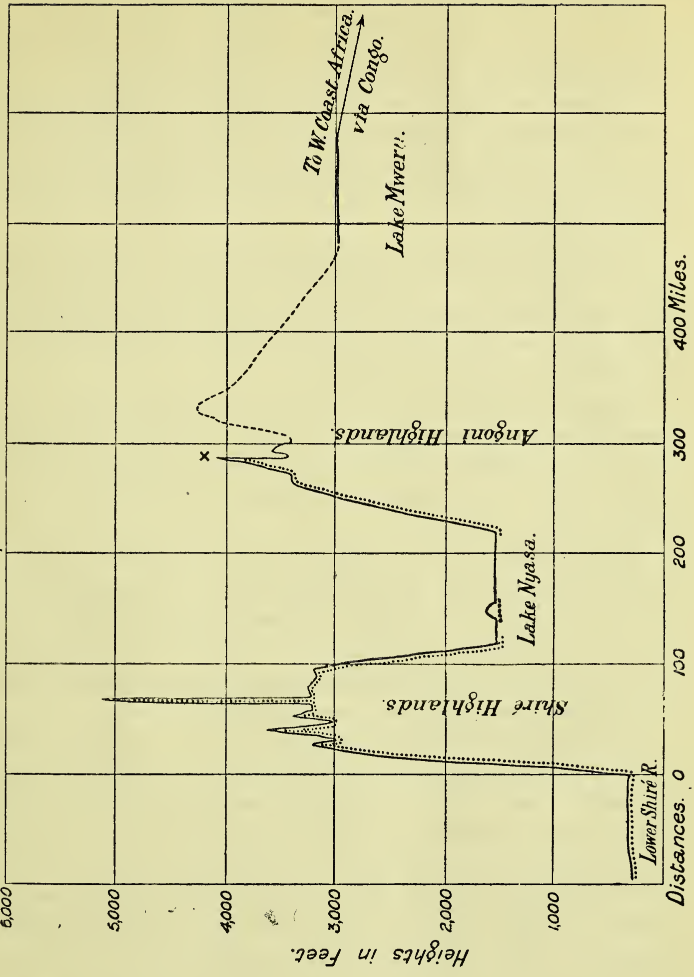
the Uganda Railway it was found in places up to a height of 3000 feet.

This mosquito is not found so plentifully in houses as the *Anopheles funestus* even where, as at the north end of Lake Nyassa, the larvæ are abundant, nor does it remain in the house in the same way.

A. Representation of section through Central Africa along the route marked A.A.A. in the accompanying Map. (Map I). The portion underlined thus .... indicates the part of the route I have traversed. All along this portion Anopheles funestus was found. The crosses indicate other points at which I have proof of the existence of the mosquito.



The larvæ are often found with those of *Anopheles funestus*, but it is also found alone in more stagnant water. It was one of the mosquitoes found in a tub on the sea coast, Chinde, at the mouth of the Zambesi.



B. *Oblique section from the Lower Shiré River, across the Shiré Highlands, Lake Nyasa, the Angoni Highlands to Lake Mweru. The portion underlined thus* .... *indicates the portion of the route traversed along which Anopheles funestus was found. This route is indicated in the Map as B.B.B.*

In some places this mosquito may be of importance, but as regards the interior it can be only of minor importance as compared with the *Anopheles funestus.*

Prophylaxis.

The evidence in British Central Africa, as elsewhere, shows that malaria is propagated by anopheles. The anopheles of most importance is the *Anopheles funestus*, as it is more prevalent and more numerous than any of the others.

There is no evidence that the parasites in the mosquito are derived from any source but man, and all the facts observed are explicable on the hypothesis that man is the sole intermediate host.

On these two points the whole question of prophylaxis depends.

A consideration of the diverse breeding grounds of the anopheles larvæ in Africa will show that whilst it is impracticable to exterminate this mosquito, yet in certain localities the number of them could be greatly reduced.

There are two classes of breeding grounds—*permanent* and *subsidiary*.

The permanent breeding grounds include springs, streams, rivers (especially when grass-grown), permanent pools, and sheltered portions of fresh-water lakes. Such places could not be dealt with by the use of kerosine or other larvicide.

Springs, in proximity to European quarters, could be drained by making wells. Streams can be cleared and kept free from obstructions. Sites on river banks avoided in places where grass-growth in the river bed is great, and where small patches only exist these could be destroyed.

So far some of the evils have been increased by artificial means. Such obstructions as dams, drifts, or stone crossings, and the deposition of brushwood or trunks of trees parallel to each other in the course of a stream, "corduroying" the bed, are particularly dangerous. Grass and other refuse from clearing the ground is often thrown into the streams, and forms an obstruction.

The *subsidiary breeding grounds* are either natural or artificial. The *natural* ones are hollows where rain water can collect; marshes, small or large, when either well supplied with fresh water or covered only with shorter grasses or rushes; pools formed by filtration from a neighbouring mass of water at a higher level.

Some of these places might be dealt with by kerosine or other larvicides. In others, extensive drainage and often embanking would be requisite. Such places should be avoided.

The *artificial* subsidiary breeding grounds are of great importance. They include irrigation systems with too limited a supply of water; badly-graded trenches; leaky trenches, and trenches overgrown with grass or otherwise obstructed. These faults should be avoided. In a well-designed irrigation system kept clear, anopheles larvæ are rarely found, unless these larvæ are present in the source of the water.

Trenches between rows such as are often made in native gardens are dangerous, with a high level subsoil water. As these gardens are made at the edges of marshes and in old river beds, in some situations, suitable collections of water readily form.

Rice fields when flooded are suitable places.

I am informed that in Russian Central Asia native gardens and rice fields are not allowed to be made within a certain distance of European

settlements, and that since this prohibition was enforced there has been a marked diminution in the malaria.

Excavations when deep, as the brick pits and native wells are in British Central Africa, do not seem to be the habitat of anopheles larvæ. Shallow pits are of more importance, but only when there is a steady rainfall or the level of the subsoil water is high. The pits made by removing earth to form railway embankments, "borrow pits," frequently contain anopheles larvæ.

These excavations are subdivided by partitions, as the work done is estimated for each gang by the amount of earth removed. A continuous excavation would be less dangerous as it would be flushed by heavy rains, and, except on level ground, would hold less water.

Distribution, as larvæ, of the anopheles takes place to some extent. The common occurrence of the larvæ in springs and at the edges of rivers enables this process to readily take place. The larvæ do not probably travel far by their own exertions, but, if swept into a stream, especially if amongst detached masses of grass, they could be carried down for indefinite distances. It is very doubtful if they would survive a passage through any extensive rapids. This indicates a danger of the possibility of these mosquitoes spreading down rivers to districts free from them, and should be considered when undertaking any extensive works in connection with rivers.

Any attempts, even in small areas, to diminish the amount of malaria by attacking the anopheles breeding grounds will be attended with some expense, and will be useless unless constant, individual and corporate, care and attention are exercised. There is no excuse for the multiplication of breeding-grounds and little justification for the optimistic view that, even without special attention, malaria will diminish as a result of European occupation. The effect of this occupation in British Central and British East Africa, so far, I consider to have resulted in an increase in the area and number of the anopheles breeding grounds in many places.

Receptacles such as tanks, barrels, &c., do not seem to be suitable breeding grounds. Shallower receptacles occasionally harbour them, as Dr. Howard found larvæ in a disused canoe, and I have found them, but not *Anopheles funestus*, in an open tub. Such receptacles it is well to have overturned.

Protection from Mosquitoes.—The main reliance in many places must be placed on protection from the bites of mosquitoes. The more efficient this protection the better, but any increase in it will be beneficial proportionately.

Mosquito-proof houses, if properly used, would be the most effective. The care required is great, and any mosquitoes obtaining an entrance would have little opportunity for escape. The *Anopheles funestus* enters houses to some extent in the daytime, so the houses must be kept per-

manently closed. Fumigation as an additional precaution would reduce these difficulties. Extensive alterations in existing houses would be required to render them mosquito proof. Wire gauze greatly checks the passage of air. To be equally cool a much larger area for ventilation would be required than the present door and window space. They would be too expensive for many people. In African houses it is essential that little woodwork be used as it is rapidly destroyed by ants.

On the whole, I consider that small low rooms of mosquito-proof gauze (wire) in thoroughly well-ventilated houses would be more convenient, cheaper, and more likely to be generally adopted. They can be thoroughly inspected and seen to be free from mosquitoes.

In the absence of mosquito-proof rooms mosquito nets should be used, even when no mosquitoes are noticed.

Many of the nets in use are faulty. The meshes are too coarse as the small mosquitoes, and particularly the important one *Anopheles funestus*, can pass through. Muslin nets are efficient, but close and hot. Something intermediate is required. Nets should be fixed inside the frame of the bedstead. If outside it is difficult to tuck under the mattresses at the corners.

Some nets are tent-shaped. These are suspended from small circular frames hanging from the roof. In such the net is so low at the ends of the bed as often to be in contact with the person's extremities. Narrow "camp" bedsteads are much used on account of their portability. In these some portion of the person is usually in contact with the net. Mosquitoes gorged with blood are often found on the outside of the net.

Some nets have a slit from top to bottom. These require such careful adjustment that they should be avoided, as unless carefully adjusted, mosquitoes obtain entrance through the slit.

Other nets are not tucked in at all, but are weighted along the edges and rest on the ground. Numerous mosquitoes are found in such nets.

The best form, I think, is the ordinary oblong net, fixed to the inside of posts at the corners of the bed, and carefully tucked in all round.

In badly-managed houses it is not unusual for the net to be simply thrown over the top of the bedstead in the daytime, and contained mosquitoes are thus retained. When the net is put down at night these mosquitoes are set free in the net and can again attack the occupant.

Clothing gives some protection. The feet and ankles are the parts most usually attacked ; high boots, leggings, or what most people will prefer, double socks, give a fair amount of protection, and so does the frequent use of various essential oils.

Much of the malaria in the Highlands of British Central Africa is acquired whilst travelling on steamers to them. On the Zambesi and Lower Shire rivers anopheles abound, and in narrow bunks with short mosquito nets there is little protection.

The time spent on this journey in actual travelling has been materially reduced in the course of the last year by the competition of various companies. There is room for further improvement, particularly in making connection where transhipment is required.

This matter is largely in the hands of missions and companies, as a time-limit for the journey should be insisted on in the contracts with transporting companies.

There should be no insuperable difficulty in making cabins and saloons mosquito proof.

It would be better, when it is impossible to travel by night, to anchor out in the stream instead of being tied up to the bank, as is now usually done. There is no need at all to tie up in the proximity of a native village.

Daily fumigation of all cabins should be done towards sunset.*

The proportion of *Anopheles funestus* infected with malarial parasites in British Central Africa seems to be small.

Exclusive of mosquitoes reared from larvæ, I examined over 1500 without finding one with a zygote. These mosquitoes were caught in European houses and kept till they had digested at least one meal of blood.

The clinical evidence points to the same conclusion, or rather to the conclusion that an infective swarm of mosquitoes is only occasionally met with.

Every person coming up to the Highlands must be bitten under present circumstances by hundreds of anopheles during the two weeks or so spent on the Zambesi and Lower Shire rivers, and yet 75 per cent. appear to escape infection. In some journeys every person gets fever; in others none.

On Her Majesty's gunboats there is a decided tendency, judging from the returns kindly supplied to me by Surgeons Vaudin and Gilmour, R.N., for the cases to occur in groups, showing that there

* For commercial purposes a railway from Chiromo to Lake Nyassa has been strongly advocated.

Such a railway would be most beneficial to the public health, as by it access would be obtained to the Shire Highlands and the lake shore without a single night being spent in the two worst portions of the country, namely, the upper reaches of the Lower Shire and the Upper Shire river.

Residents on these portions of the river are mainly stationed there in connection with transport work; and, if the railway were made, the number of European residents in those places would be reduced; a large decrease in the amount of malaria would certainly result, and probably a decrease in the amount of "Black-water Fever."

are periods when no infections take place. These periods in several instances were over a month.

The paucity of infected mosquitoes I attribute to the small number of cases in which crescents are found in large numbers. Out of 220 mosquitoes (*Anopheles funestus*) fed on patients in whose blood one crescent was found after repeated examinations, none developed zygotes.

These poor crescent cases seem to be the rule alike in Europeans, natives (both adults and children), and Indians in British Central Africa.

There can be no doubt that the natives are the common source of the parasites. It is no new discovery that children in malarial countries are not only not immune but are almost all attacked by fever. In British Guiana, a moderately malarial country, this prevalence of malaria has been long known clinically.

Out of 1289 unselected post-mortem examinations on persons, natives of British Guiana or coming from other malarious countries, microscopical examination of the spleens showed malarial pigment as follows :—

Under 1 month	Nil.	
,, 6 months	25·	per cent.
,, 1 year	21·4	,,
,, 2 years	54·5	,,
From 2 to 5 years	81·4	,,
,, 5 ,, 10 ,,	67·5	,,
,, 10 ,, 15 ,,	77·	,,
,, 15 ,, 20 ,,	52·3	,,
,, 20 ,, 25 ,,	37·9	,,
,, 25 ,, 30 ,,	30·3	,,
,, 30 ,, 35 ,,	17·9	,,
,, 35 ,, 40 ,,	14·1	,,
,, 40 ,, 50 ,,	13·2	,,
,, 50 ,, 60 ,,	11·1	,,
,, 60 and over	11·6	,,

and I further pointed out that over twenty the pigment was "very rarely recent." ('British Guiana Medical Annual,' 1895, 57–61.)

That the same is the case in British Central Africa is shown both by the prevalence of malaria, verified by blood examination in the children, and by the fact already reported that children free from manifestations of malaria in several instances have parasites. The age-incidence of enlarged spleens as reported from time to time confirms this view. Professor Koch has demonstrated more directly elsewhere the enormous preponderance of the infections in children.

As therefore the native population is a constant source of danger, it is not advisable that European settlements should be near native settlements. In Russian Central Asia, none are allowed within a certain limit. In British Central Africa, even where native houses are not allowed in the portion allotted to Europeans, they are allowed close to and often surrounding it. No order, cleanliness, or spacing is insisted on, and the houses are placed as close together as the people like. In missions, the school children are often resident on the mission grounds and must be a source of some danger.

It must always be remembered that in a European, convalescent from an attack of fever, his parasites will be in the stage capable of being transmitted to the mosquito, and he must be well guarded against the attacks of mosquitoes, both for his own sake and his neighbours. With such an inmate thorough fumigation of the house should always be practised.

It is so commonly stated that alcoholism is a cause of the sickness and mortality in Africa, that I think it well to state here that it is not common in British Central Africa. Such cases as occur do not appear to suffer more from fever than others, whilst the sickness and deaths amongst abstainers, including missionaries, is so great as to show that abuse of alcoholic stimulants can have little to do with the matter. There are individual exceptions.

As good living as is procurable is of importance, not that it diminishes the susceptibility to malaria but that it enables more rapid recovery.

Sufficient attention is not paid to sanitation in its widest sense. Sanitary works are usually performed either by local boards or a general board of works, with or without medical advice. They are not directly under the control of a medical department. Money set apart to the medical departments is entirely absorbed in treating disease, *i.e.*, for hospitals, nurses, &c., and little or none spent in preventive medicine. Most of the money for public works is spent on public buildings and improvements which may be indirectly beneficial to the public health or not.

Money devoted to preventive medicine or sanitation should be kept apart from either the medical or public works votes, and accounted for separately.

A separate department for sanitary affairs distinct either from public works or the medical department would I think be advantageous in most places.

In conclusion I am of opinion that unless the amount of malaria can be materially reduced, colonisation by either Europeans or Asiatics cannot be successful in Tropical Africa.

There is also grave doubt whether even the negro population is increasing except in the more healthy districts. The climate is quite

suited for Europeans in the Highlands, and the country in part at least is fertile, but under present circumstances cannot be utilised, and any increase in the susceptible population without a corresponding decrease in the anopheles would probably lead to an increase in malarial diseases.

In the above I have limited myself to malarial infections from external sources. I have no doubt that exposure to sun, chills, over-exertion, and excess of all kinds in persons harbouring malarial parasites does bring on outbreaks of malarial fever. Such causes usually produce their effect speedily and not after a prolonged period of incubation. For prophylaxis avoidance of these causes is essential.

Notes.

Note on Occurrence of Anopheles in Madagascar.

In the course of the few hours spent at Nosi Bé I was able to examine streams of two kinds. In the one there was a series of water holes connected by a small running stream. Algæ were abundant. Anopheles larvæ and more abundant culex larvæ were found. In the other class the stream was clear and with little vegetation. Anopheles larvæ alone were found. The larvæ did not hatch on board ship, and I could not identify them, but they were not those of the "small black" anopheles. Two kinds were found.

Note on Occurrence of Anopheles in Zanzibar.

The country behind the town is gently undulating. In some of the hollows between the undulations there are extensive superficial pools. The grass at the edges is short, and beyond it are rushes and water lilies. Anopheles larvæ of two kinds were found, but, as with those at Nosi Bé, I failed to hatch them and could not identify them.

Such a situation in British Central Africa would have been covered with tall rank grass over 6 feet in height, and the water peaty and putrid.

Note on Food of Anopheles Larvæ.

The contents of the intestines of the larvæ are mainly vegetable matter, and in most cases entirely so. Occasionally limbs of minute insects or crustaceans are found as well as scales of mosquitoes or other insects.

On watching them feeding, it is seen that all minute particles are drawn to the mouth, but many of them are rejected. This rejection is somewhat arbitrary, as a particle at first rejected is often subsequently

swallowed. Amongst the bodies seen to be swallowed I have seen living minute crustaceans and young larvæ, both of anopheles and culices, but, as a rule, living animal bodies either escape or are rejected.

The feeding, with the young larvæ, seems to be entirely at the surface; but the more mature often descend in shallow water and feed at the bottom.

Note on the Supposed Opposition between Larvæ of Culex and Anopheles.

Either larvæ may be found alone, but in many situations both are found together, and often several species of each. At least five species of culex have been found with anopheles larvæ.

The less the movement of the water the greater the probability of culex larvæ being also found, and in a grass-grown river the anopheles larvæ will be more abundant near the stream and the culex larvæ near the bank.

Note on the Effect of Fish and Insect Larvæ in Destroying Anopheles Larvæ.

There is no doubt that, in confinement, fish, and especially young fry and small fishes, will speedily destroy the mosquito larvæ, but in spite of this, anopheles larvæ are often found in pools, rivers, &c., where fish are abundant, and pupa and mature larvæ amongst them. This is seen in open pools as well as in the grass-grown rivers.

Tadpoles do not attack the larvæ, even in captivity. Larvæ of Coleoptera and Dragon Flies are often found in numbers in water with abundant anopheles larvæ, and even in captivity do not seem to devour them.

Note on the Proximity of Anopheles Breeding Grounds to Human Habitations.

No relation has been observed in either British Central or British East Africa. Anopheles breed in permanent fresh water, and human habitations are also usually placed near such fresh water, but the larvæ are often found abundantly in suitable places which have not been selected by man also for habitation. Anopheles will feed on many animals besides man, so that even if mammalian blood is a necessity for their breeding, they have other opportunities of obtaining it.